CDF 2010 performance and physics highlights

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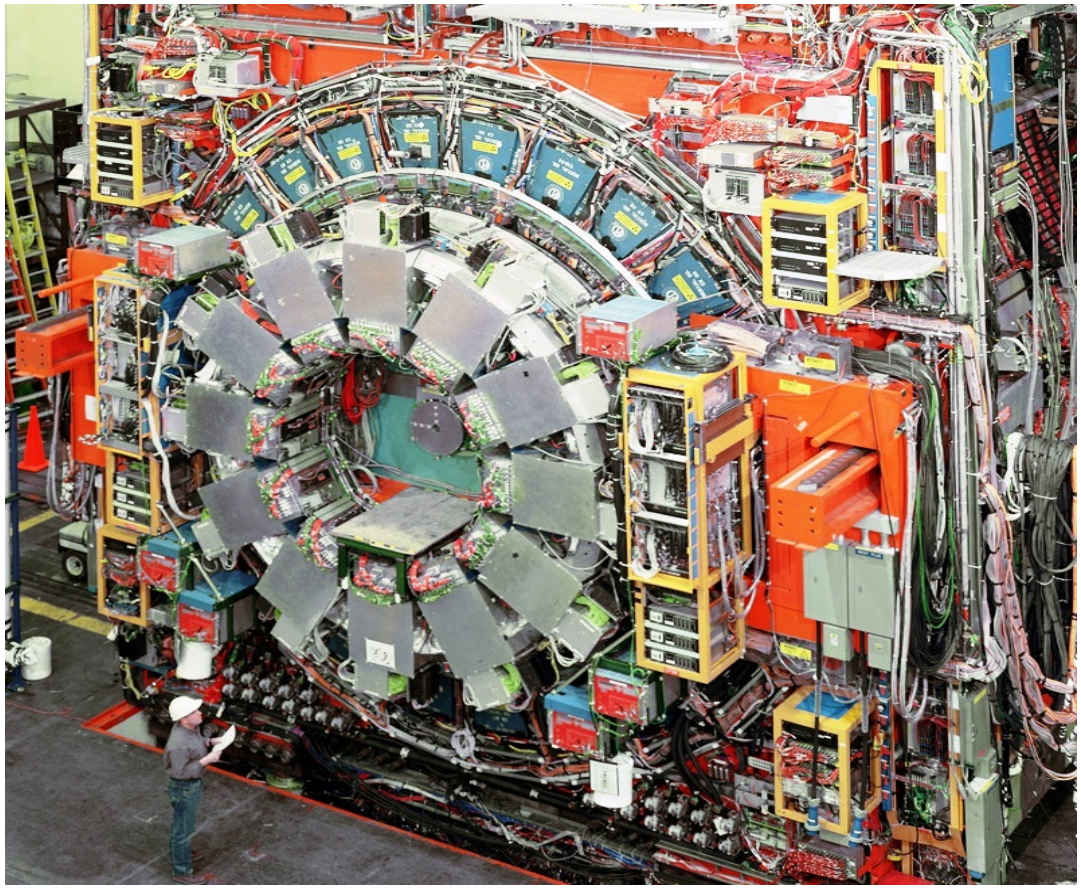
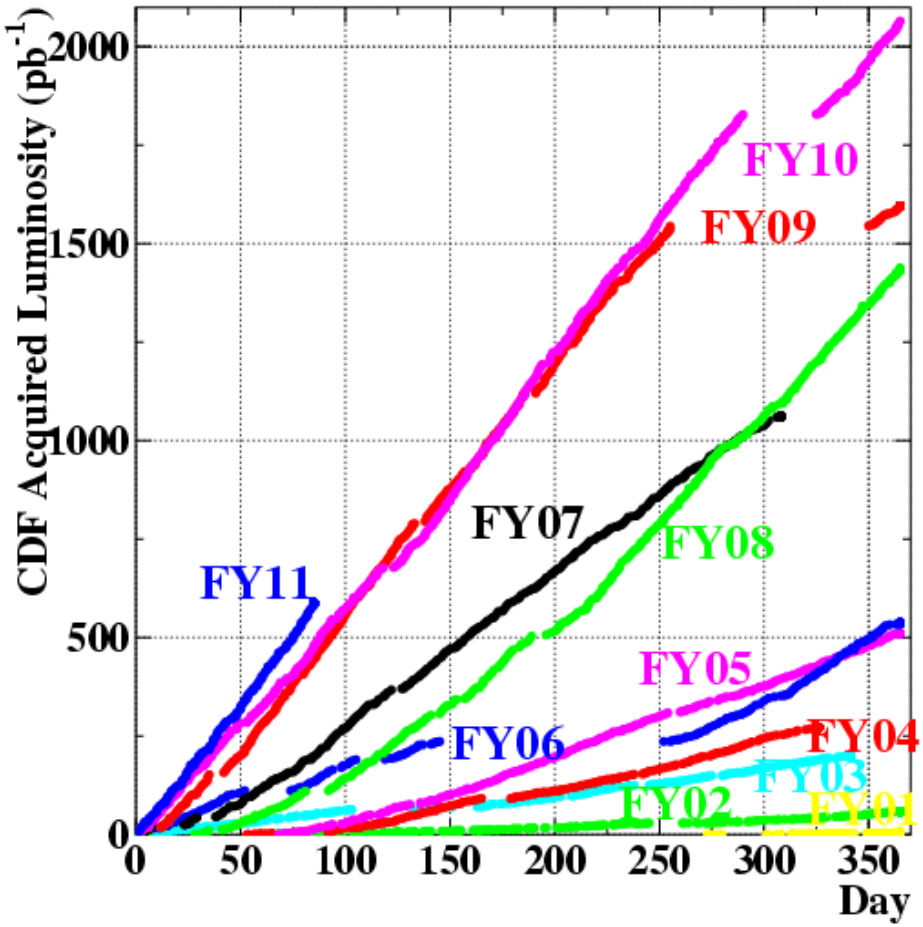
CDF International Finance Committee

Jan 10, 2011



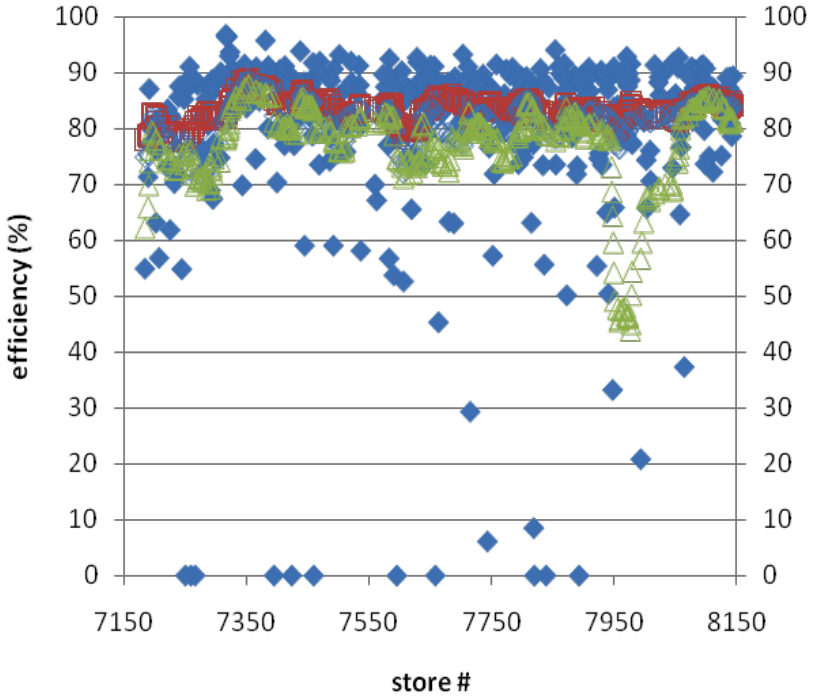
A Luminous Year



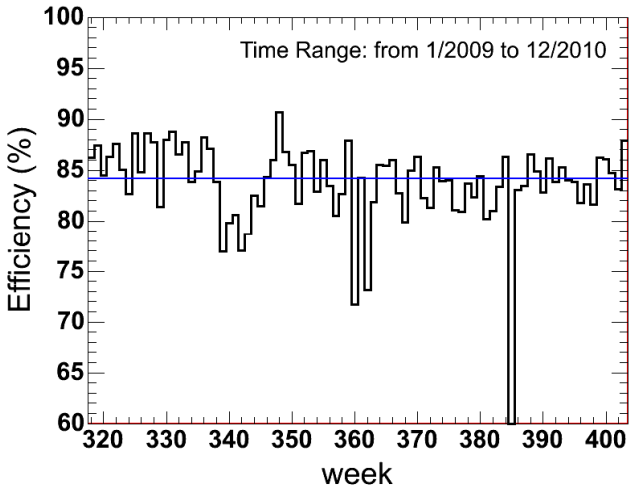
FY 2010 integrated luminosity delivered 2.5 fb^{-1}
of which CDF recorded 2.1 fb^{-1} to tape.
Run II total 9.5 fb^{-1} delivered at end of FY10. *Today >10 fb^{-1}*

CDF Data Taking Efficiency in 2010

integrated luminosity (1/fb)	Run II		FY09		FY10	
delivered	9.5		1.8		2.5	
recorded	7.9	83%	1.6	85%	2.1	84%
good	7.5	79%	1.5	82%	2.0	82%
good w. silicon	7.2	76%	1.5	80%	2.0	80%



Keeping it high !



Results come from hard work

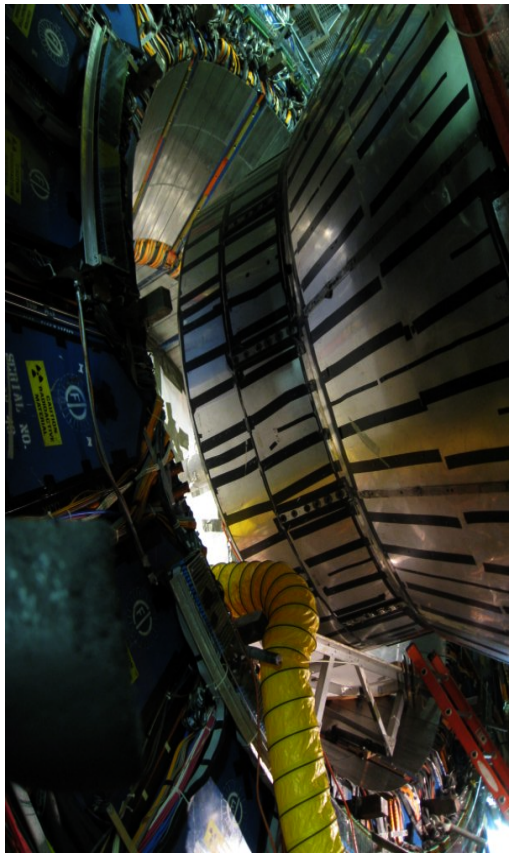
- **Stable efficiency does not mean the ship sails by itself**
- **Lots of regular maintenance work**

A sample list of jobs (5 months: February to June):

27 controlled accesses (~1.4/week), mostly opportunistic:

- Silicon: replaced 2 power supplies and 2 FIB boards; reconfigured 1 FIB and 1 power supply, investigated and debugged some problematic ladders;
- SMX: replaced 1 power supply.
- Calorimeter: replaced 3 plug HV modules, 1 WCAL CPU card and 1 CAFE card, reset or checked a couple of Pisa Boxes, fixed WCAL02 power supply.
- COT: replaced 4 power-supplies and 1 TDC board, reseated 2 repeater cards, repaired the remote reset cable for a power supply, installed a remote power-cycling box.
- Muons: replaced 1 BMU power supply and 4 BSU/1 TSU CCU modules, work on CMX HV system.
- Infrastructure: replaced 1 vacuum pump.
- Tested safety systems.

Summer shutdown



- 4 weeks: 7/18 to 8/21
- Maintenance/preventive maintenance
  - COT routine high voltage repairs both ends
  - fixed low voltage short which had killed a COT octant in SL4.
  - Silicon det. junction cards re-seating: recovered 2 ladders.
  - Silicon power supply maintenance and light level measurements
  - Front end crates and rack protection preventive maintenance
  - "As founds" of the low betas and the east beam pipe plug to toroid
  - Maintenance, calibration, testing and certification of the hall life safety system
  - Inspection of the fall protection systems
  - Replacement of online database machine and updates of servers' OS
  - Preventive maintenance of:
    - motor generators, diesel generator, UPSs, APACS (cryo control system)

Improvements

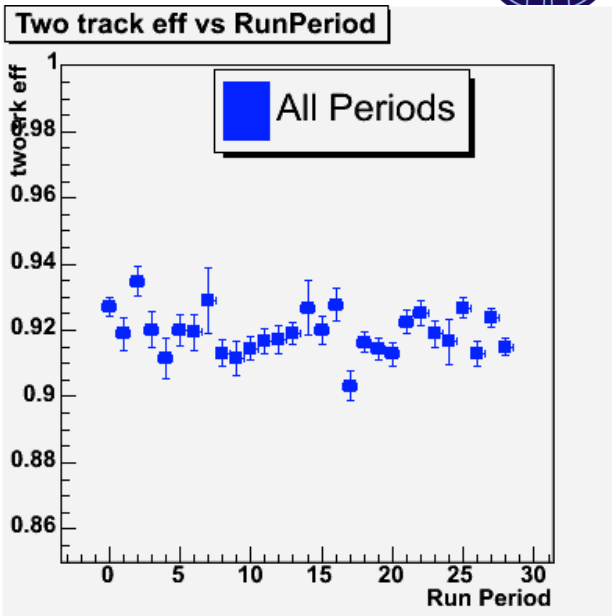
- The trigger upgrades allow to cope well with the larger luminosity (more than x30 since the start of run II)
- Completed the GigaFitter upgrade: driving SVT since Feb. 19
  - Consolidated boards, greater speed, and allows greater flexibility and increase in acceptance
- Silicon Monitoring improved - adjust parameters over time to keep optimal performance

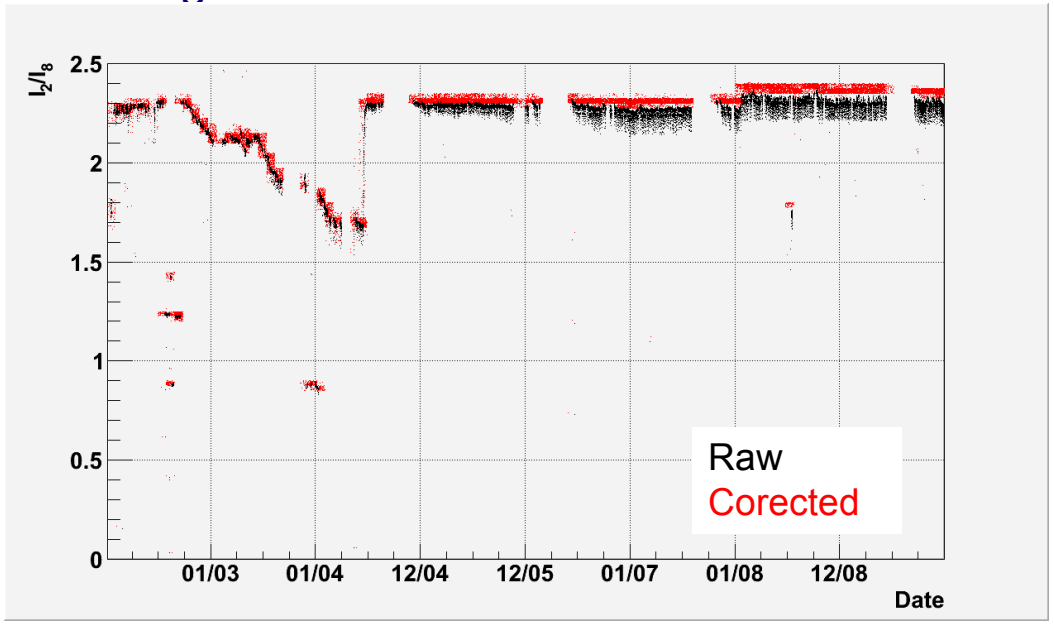
Looking at the future: Long-term detector stability

- We have been operating under the guidance of a detector vulnerability study performed in 2007 using outside "consultants".
- A new Tracker Review was held on 6/7/2010 organized by PPD Head Mike Lindgren and Tevatron Spokes.
- Dan Green chaired committee – other members include Steve Worm(Rutherford Lab), Rainer Wallny (UCLA) , Marcel Demarteau (FNAL), Alan Bross (FNAL)
- Each Collaboration Gave 3 talks
  - Overview of the Experiment
  - Status of Silicon Detector
  - Status of outer tracker

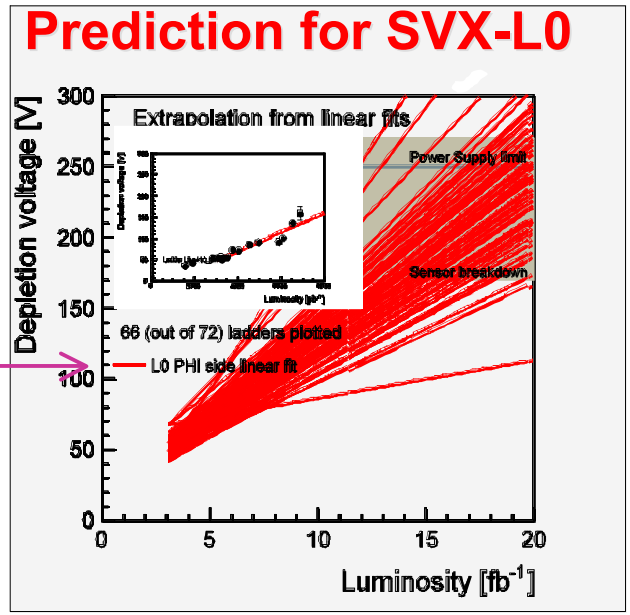
COT longevity

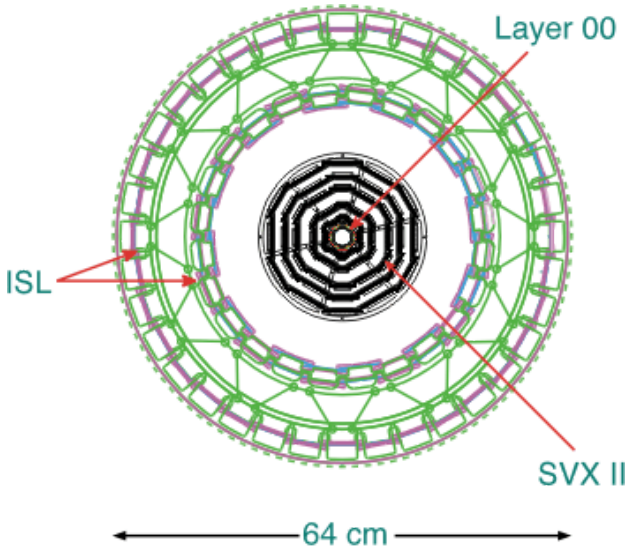
- COT is doing very well (as most of the detector)
- Tracking efficiency in Z events stable over time.
- No issues expected from radiation dose in COT materials up to ~20 fb^{-1}.
- No evidence of wire aging or gain loss after adding O_2 and improving the gas recirculating system.
- Possible issues:
  - shortage of high voltage modules.
- Possible improvements:
  - expansion of the HV system to provide more current.





Most significant detector concerns





1. Accumulated radiation damage to Layer-0 of the SVX may prevent us to fully deplete silicon.
   - Loss in efficiency - Loss in b-tag - Lost Higgs efficiency
   - ACTION: EVALUATED IMPACT ON HIGGS SENSITIVITY

2. Radiation Damage to digital optical transmitters (DOIM) may prevent reading out some parts of the detector
   - ACTION: STUDIED IN MORE DETAIL AND PLANNED A FIX

Issue #1: extreme scenario: Layer-0 unusable

- We need to evaluate how well we can perform b-tagging with a deteriorated L0

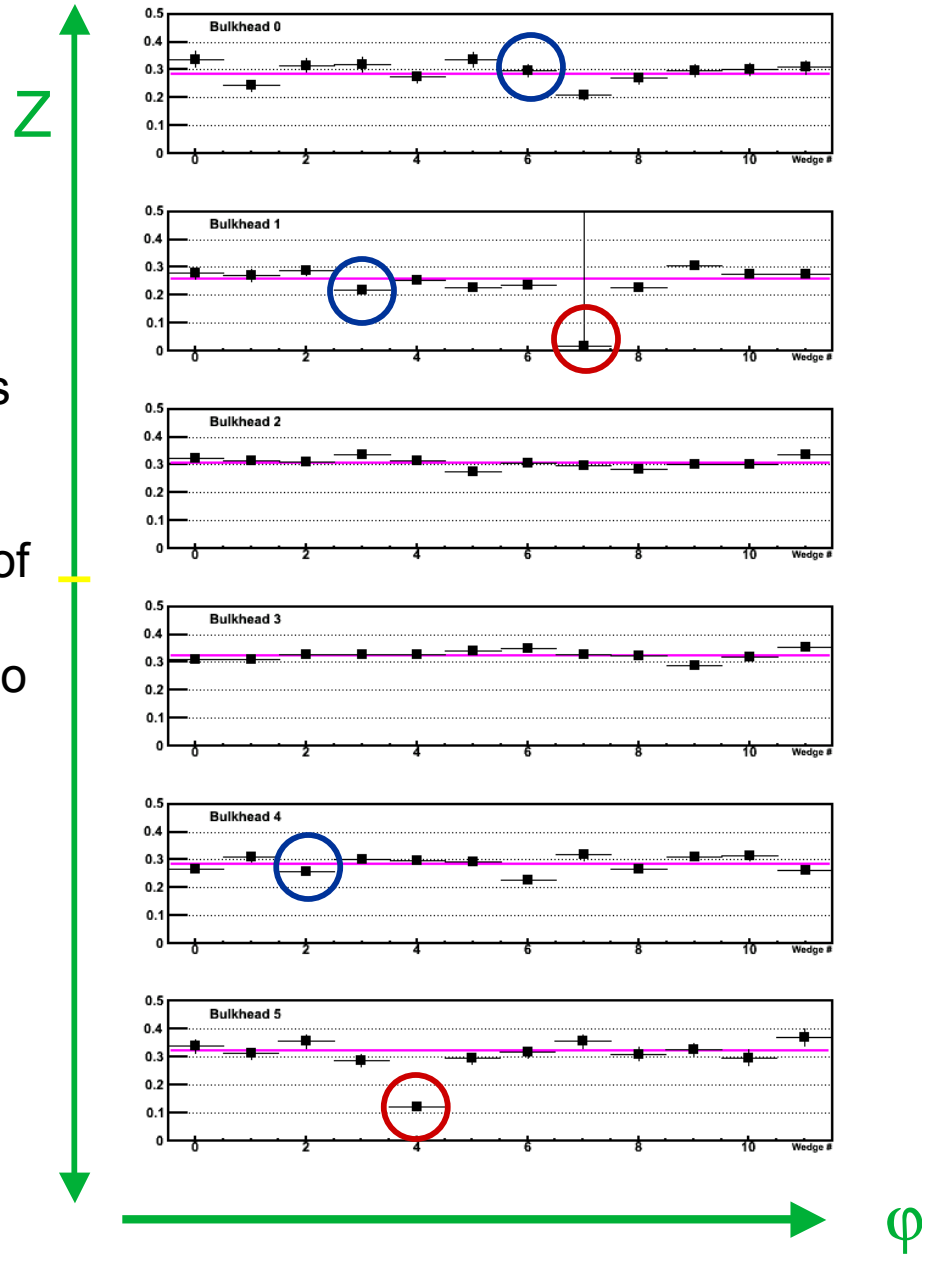
-We do this on REAL DATA, using a b-enriched jet sample tagged by a lepton

- We currently have 3 damaged SVX wedges where L0 is dead since long.

-Plot at right: **b-tag efficiency** as a function of the SVX wedge the jet is hitting.
(Separate evaluation of b-tag errors shows no statistically significant effect)

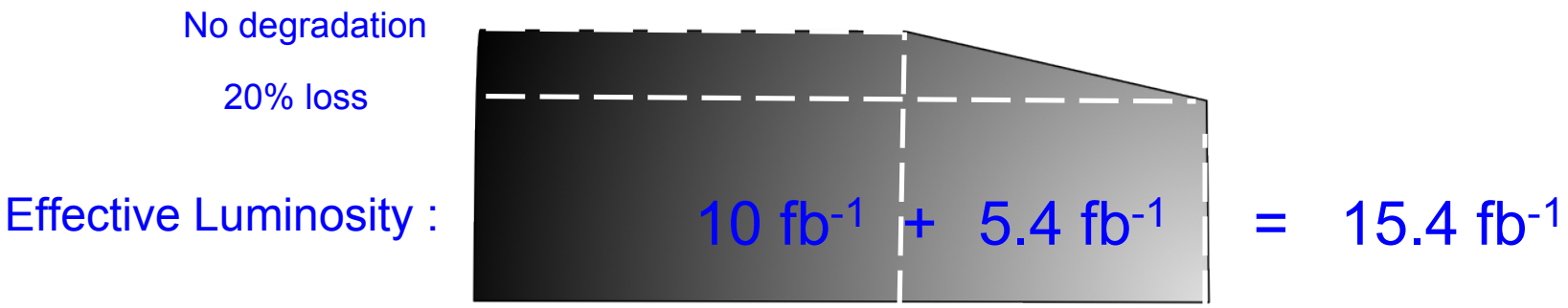
-Red circles: completely dead wedges.
-Blue circles: Layer-0 dead
- Line is fit to efficiencies for wedges by bulkhead, excluding damaged wedges.

-Even complete *loss* of L0 barely noticeable - estimate a 10% effect.



Effects on CDF Higgs sensitivity

- **No degradation in first 10 fb^{-1} of acquired data**
  - **Slow degradation in single b-jet tagging efficiency toward 10%**
    - **Implies 20% loss for pairs of tagged jets**



Overall sensitivity loss

at m_H = 115 GeV : 2%

at m_H = 135 GeV : < 1%

at m_H = 160 GeV : ~0%

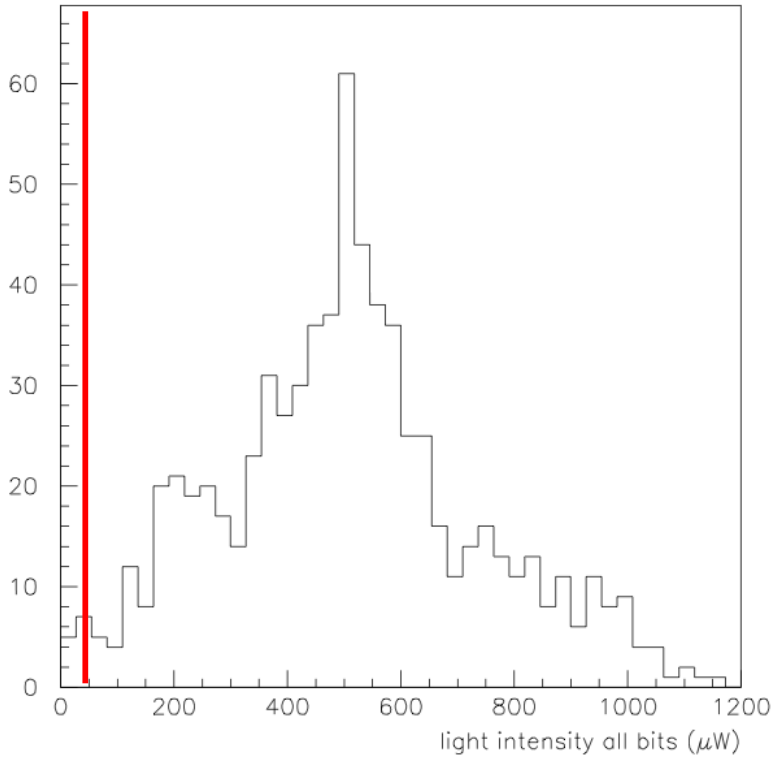
Issue #2: Decline of Digital Optical transmitters

•They carry silicon detector digitized data to the readout system.

•We recently measured the light output of 1/4 of the channels in the SVX detector.

•Distribution of light output for all measured bits shows most are currently well above the threshold (red line), but we found a 25% decline over 7 fb^{-1}

-A few may be in danger of falling below threshold, preventing data readout for the corresponding portion of the SVX



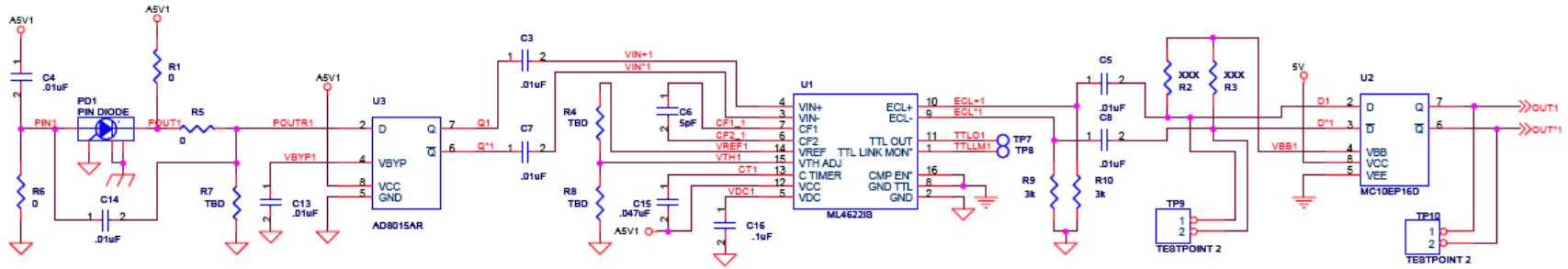
Remedy

- We don't want to take any chances and have prepared a backup solution

•A new light-amplified board ("Bit Booster Board") with more sensitive light receivers (down to ~15 μW).

• The BBB will sit in the empty slots of current FTM crates, receive light from the TX's, treat each bit separately for amplification or attenuation, and re-emit light at levels appropriate to our current RX's.

•With this board we are confident on no loss of ladders until well over 20fb^{-1} (we actually expect to *recover* a few weak ones, gaining back some efficiency)



Other subdetectors and infrastructure

- Calorimeters, ToF, Muon systems: no action to be taken.
- Luminosity and loss monitors:
  - may need another round of replacing PMTs.
- Mechanical infrastructure:
  - the solenoid and cryo system are running smoothly;
  - one or more of the older chillers may need to be rebuilt.
- Computer infrastructure:
  - expected more or less painful to solve issues due to hardware/software incompatibility as the older machines have to be replaced or the support of software products is discontinued.

Data Analysis

- Achieved great success in keeping up with data taking
  - Winter 2009, 2 to 3/fb (not as much new data as we had hoped).
  - Winter 2010 up to 5.4/fb (+many new analyses)
    - 35 NEW results

      http://www-cdf.fnal.gov/physics/W10CDFResults.html
  - Summer 2010 up to 6.7/fb
    - 37 NEW results ! Big showing at ICHEP (>40 Tev talks)

      http://www-cdf.fnal.gov/physics/S10CDFResults.html

- Number of channels used in Higgs analysis keeps increasing and analyses keep being improved.
  - Sensitivity keeps improving faster than Sqrt(L)

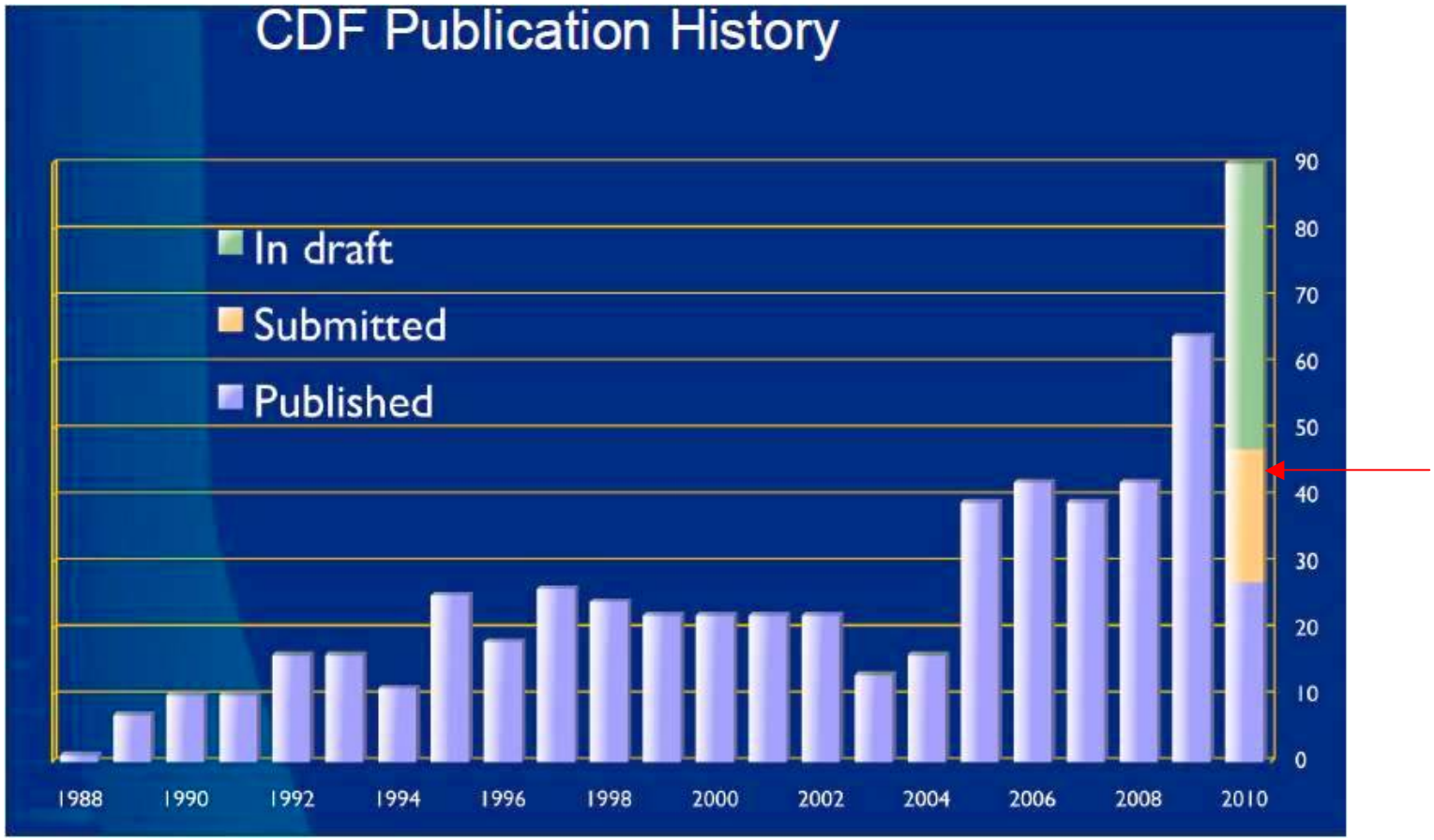
- For the first time we managed to re-process past data.
  - We now have better understanding and better reconstruction software - a wish list of improvements had been growing
  - Now is the time to go back and apply improvements to past data
    - Also makes for greater uniformity
  - Achieved re-production and re-ntupling of ~1/3 of past data
    - Expect improved b-tagging next year for Higgs (and other) results !
  - Preparing further improvements in ntuples

    -> Details in the computing talk by Ray Culbertson

Our Current Management Team

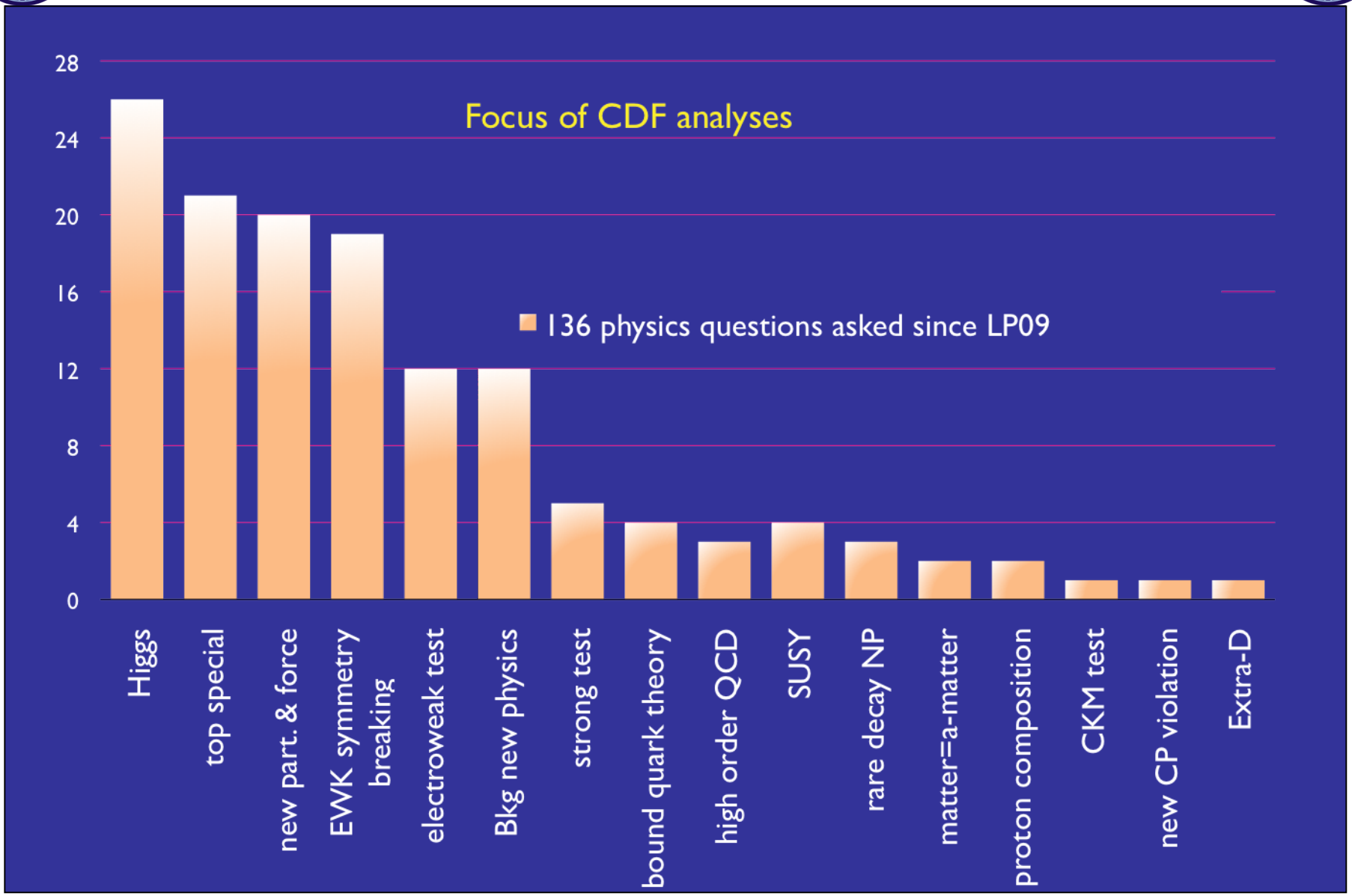
- Physics Coordinator
  - (Kevin Pitts)
- Detector Operations Heads
  - Massimo Casarsa
  - Phil Schlabach
- Offline Heads
  - Rick St. Denis
  - Ray Culbertson
- TDWG
  - Heather Gerberich
  - Simone Donati
- Higgs
  - Ben Kilminster
  - Eric James
- Top
  - Tom Schwarz
  - Fabrizio Margaroli
- EXOTICS
  - Simona Rolli
  - Oscar Gonzalez Lopez
- EWK
  - Mark Lancaster
  - Larry Nodulman
- Flavor
  - Diego Tonelli
  - Robert Harr
- QCD
  - Mary Convery
  - Christina Mesropian

CDF publication output

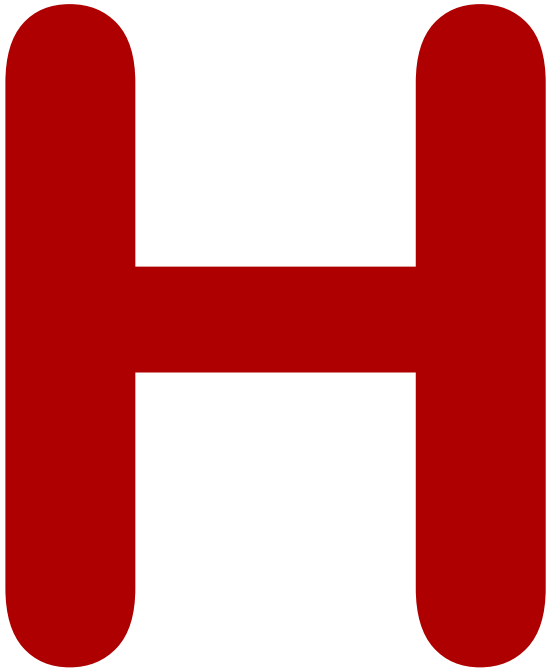


Total 43 papers published in CY 2010
(CDF+D0 account for ~50% HEP paper production in US)

CDF results by topic

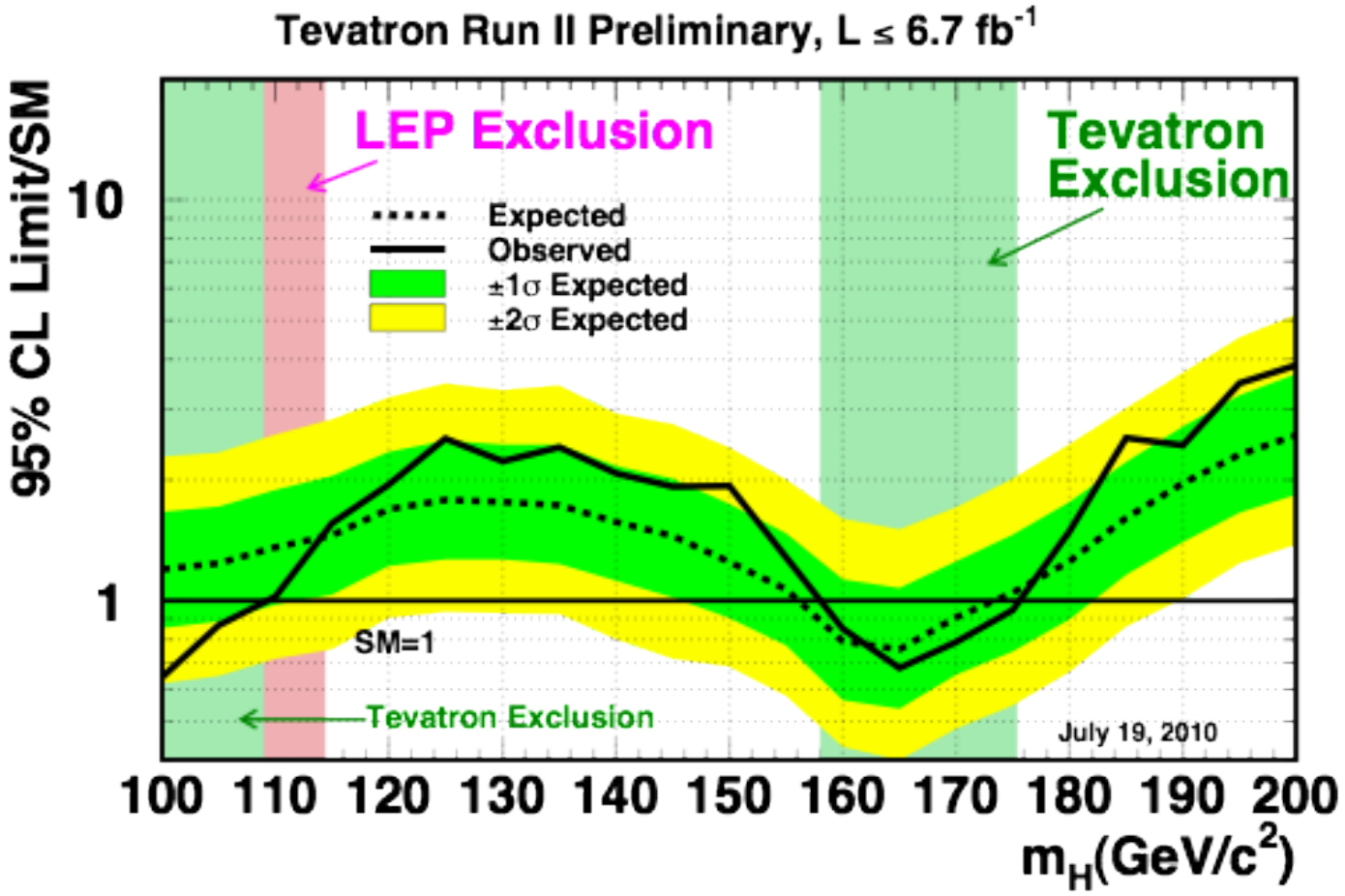


Some Physics Highlights



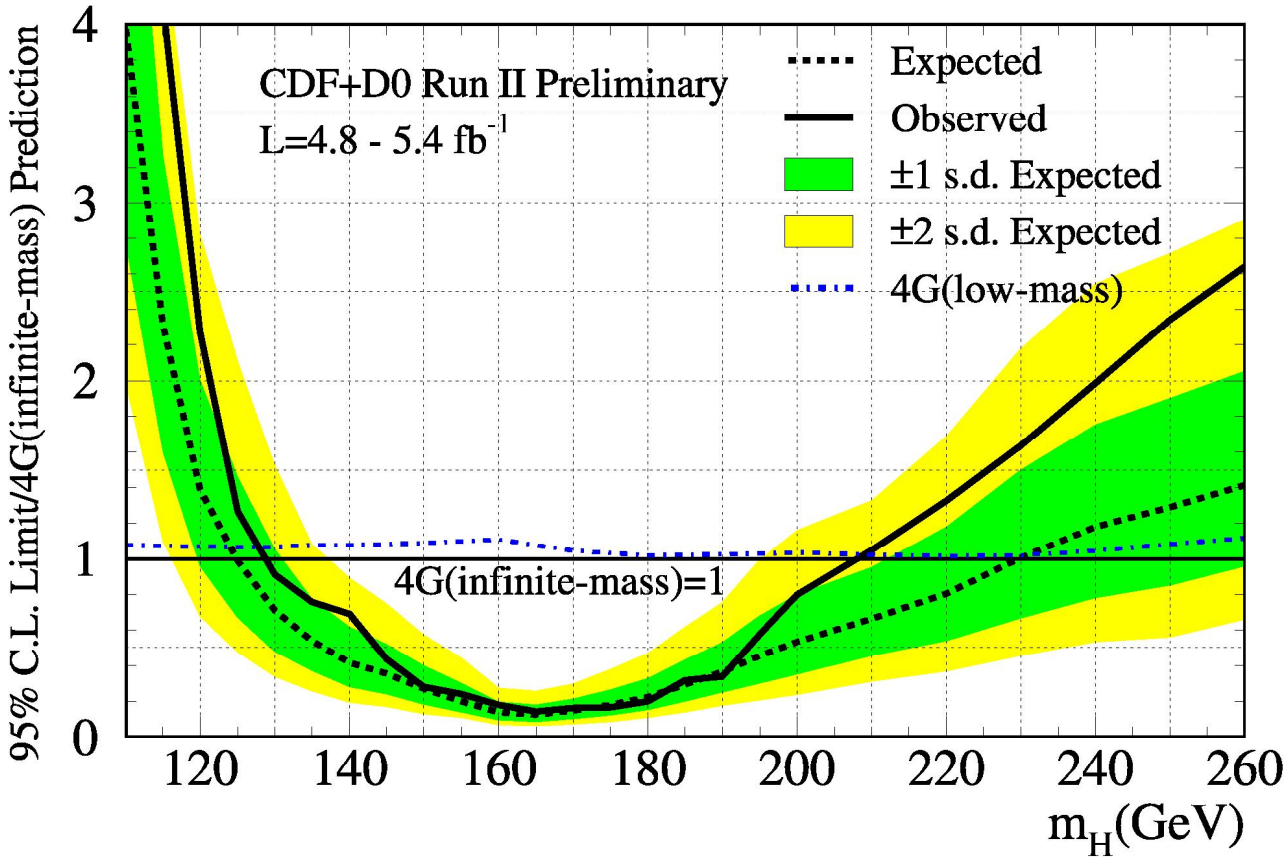
The Higgs Era begins in 2010

ICHEP 2010



Exclude 158-175 at 95%CL

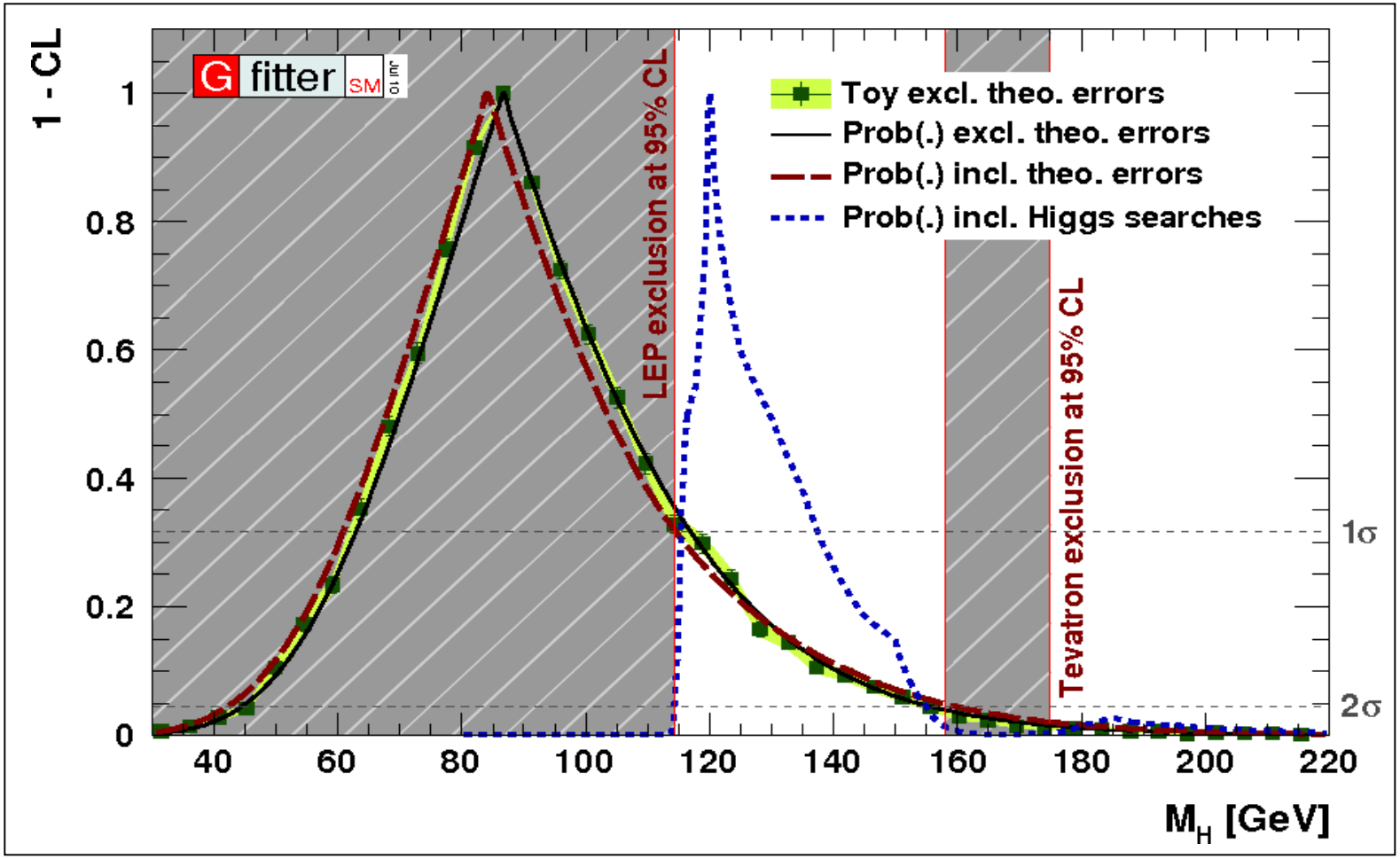
The Higgs, in a 4th gen. scenario



- Fourth sequential quark family ⇒enhance gg->H by ~9x
- 130 <m_H < 210 GeV already excluded at 95%CL !

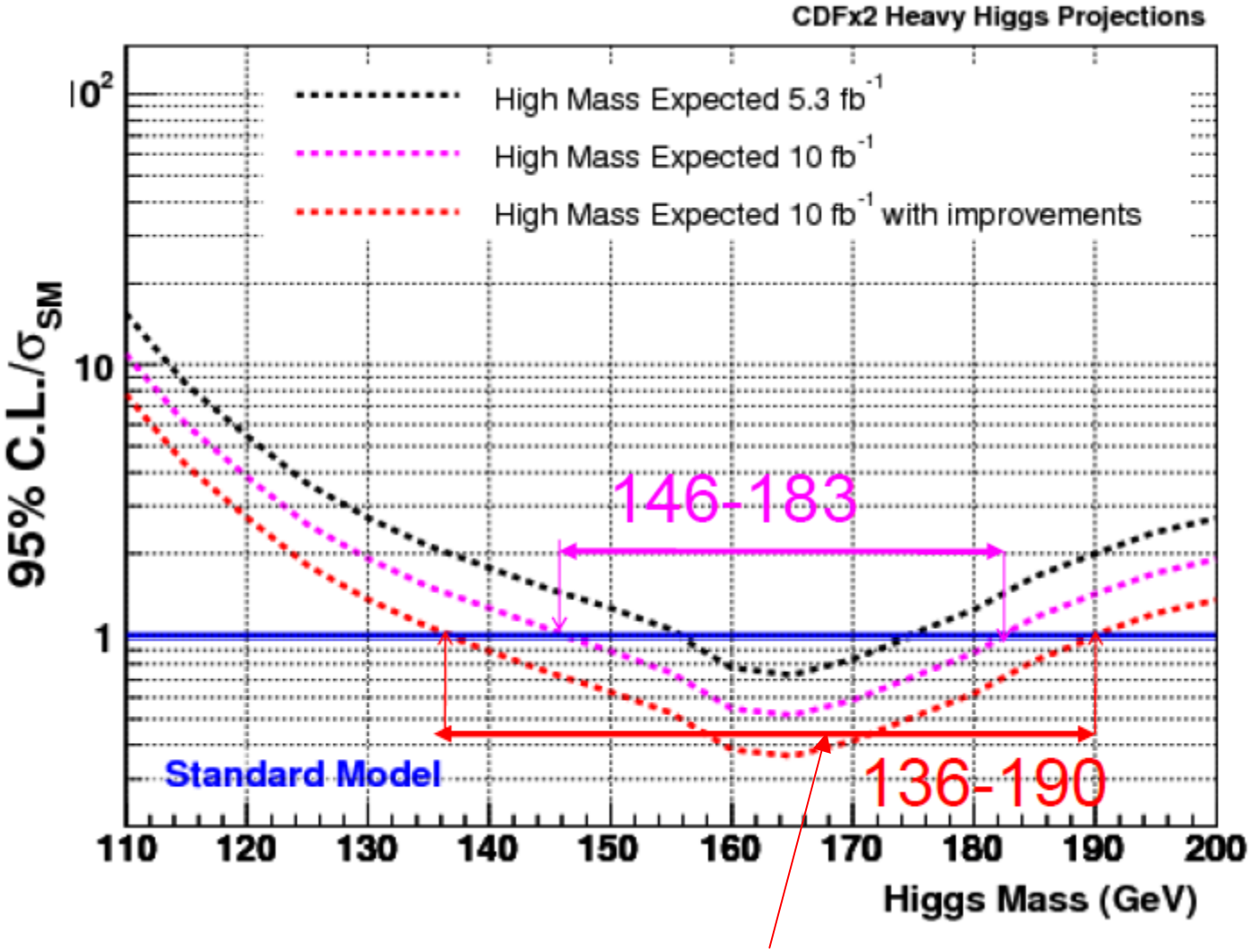
(but 4th generation tends to push m_H to higher masses)

Together with indirect info, strongly constrain SM Higgs Mass



The high-mass region is now pretty strongly disfavored

Fast progress: How it will look like next year (Hi-mass search only)



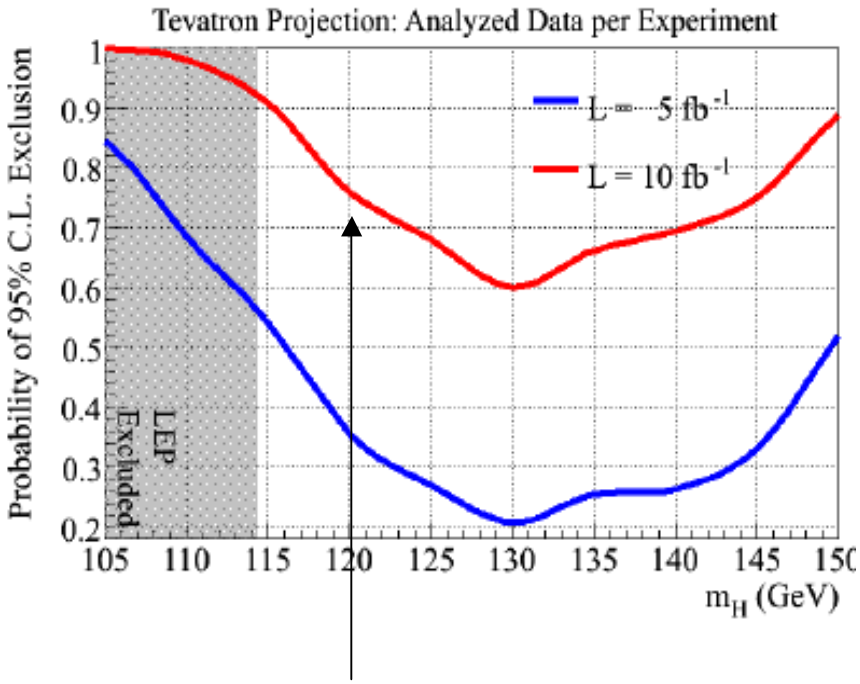
Wipe out the whole high-mass range, by direct search !

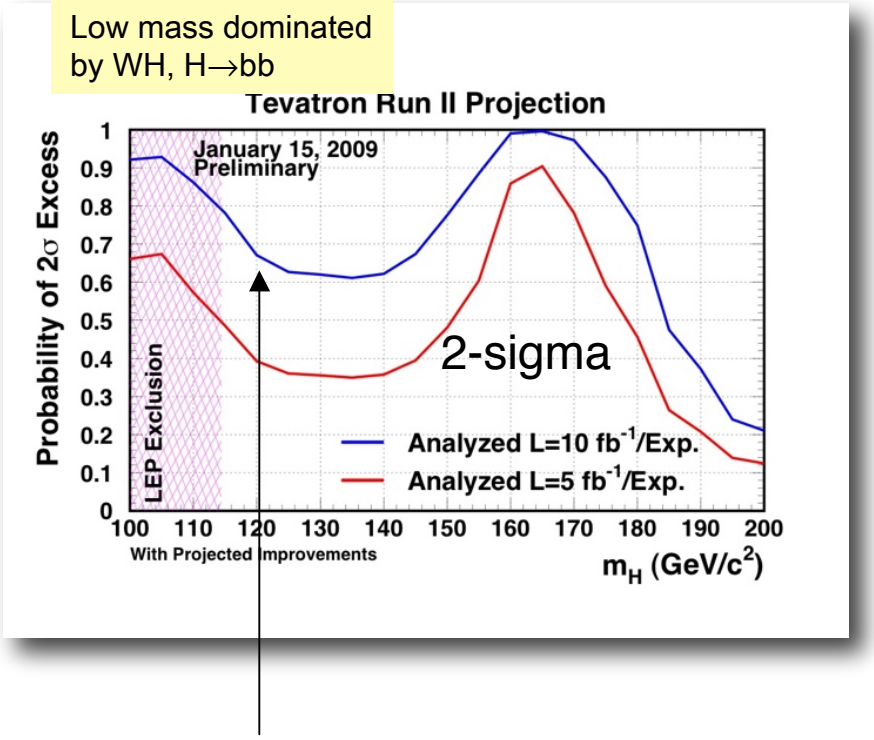
Higgs Outlook for FY11

(combined Hi+Low analyses, with improvements)

Exclusion

Discovery

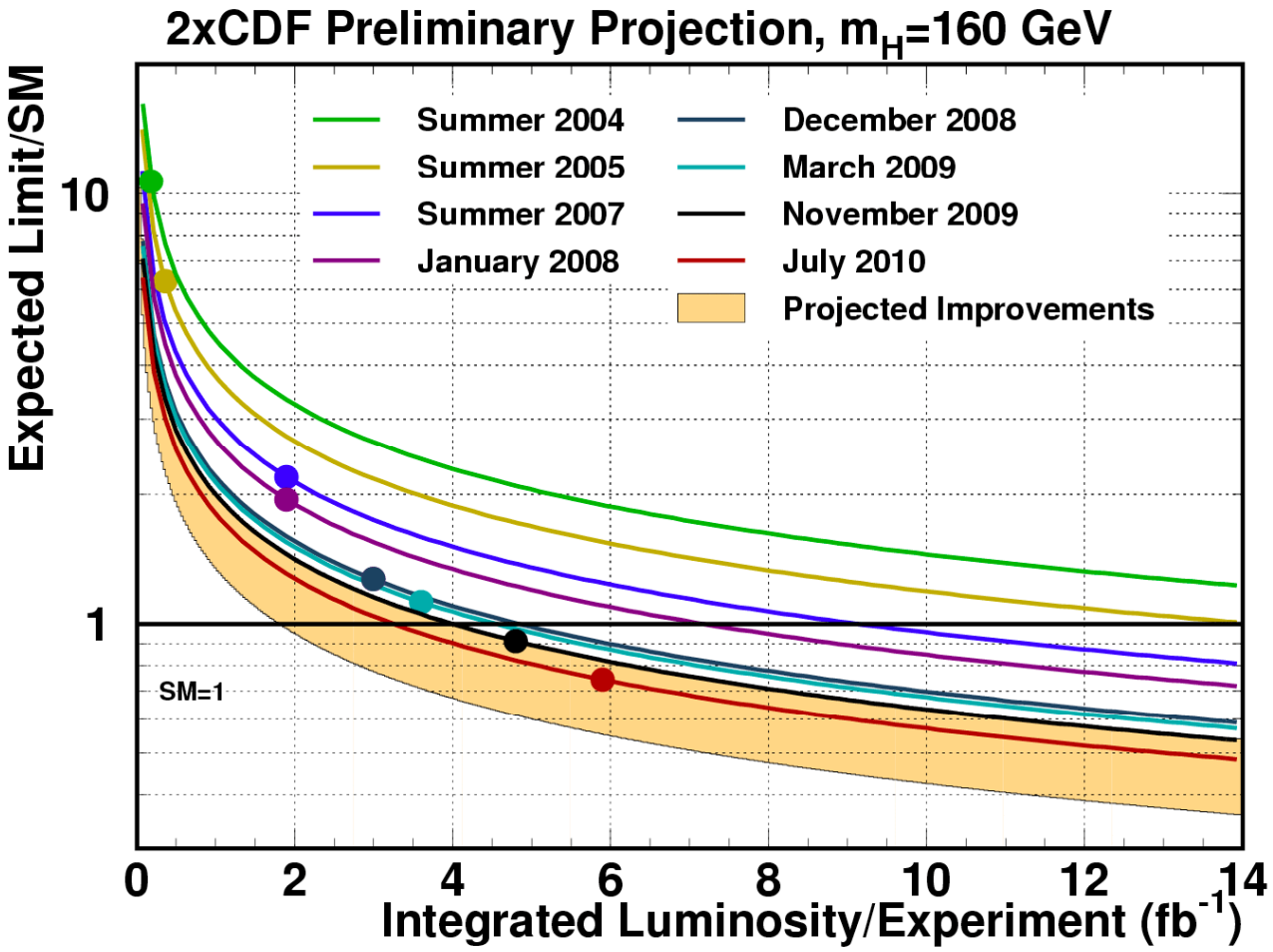




If there is no low-mass Higgs a 95% exclusion is very likely

If there is, a 2σ excess is very likely to appear

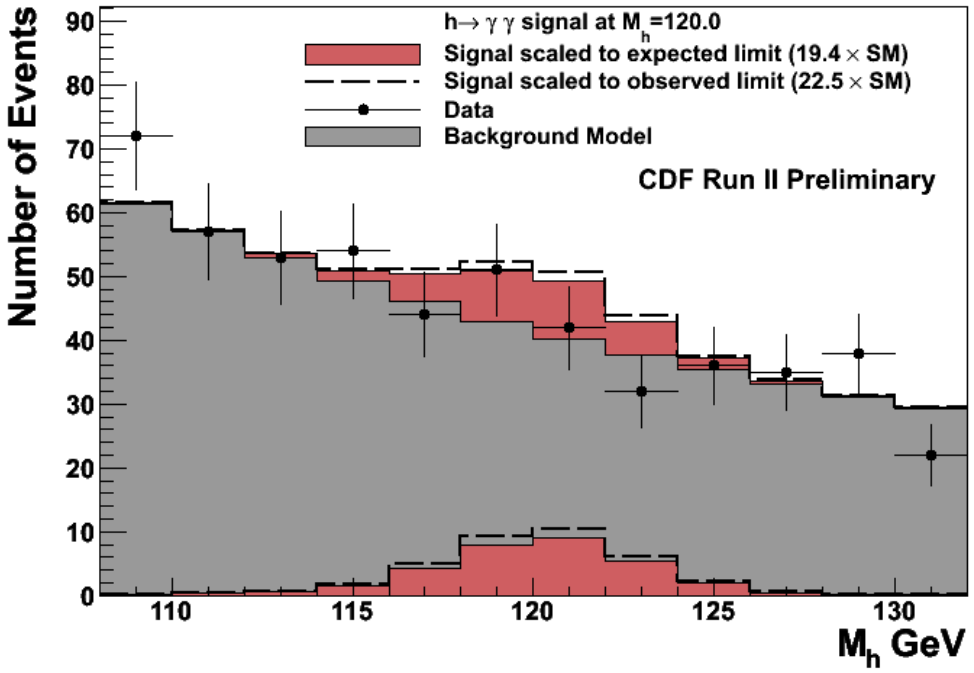
Kept improving sensitivity in 2010

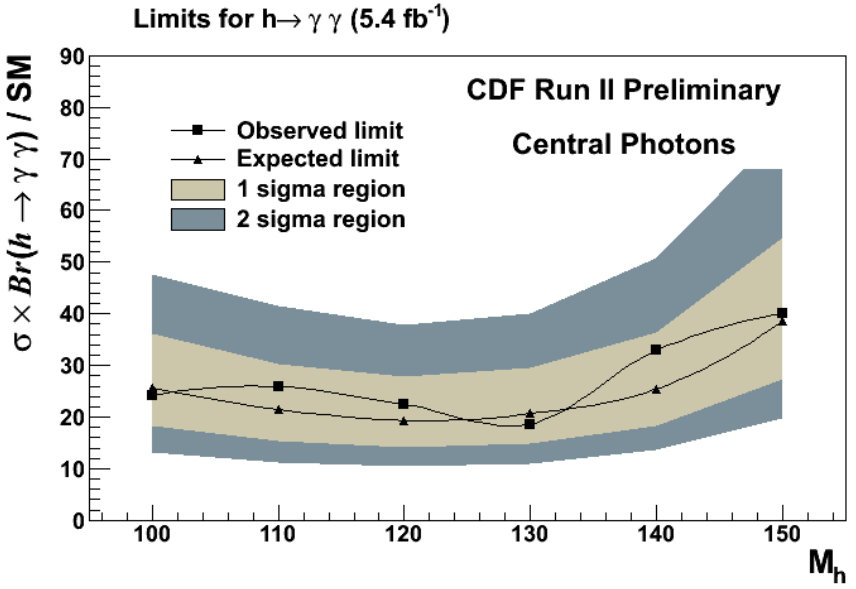


Orange band = expected improvement factors from 2007 analyses [x1.5 and x2.25]

First dedicated H→γγ search

- **H→γγ with 5.4 fb^{-1}**
  - **Excellent di-photon mass resolution makes resonances detectable**



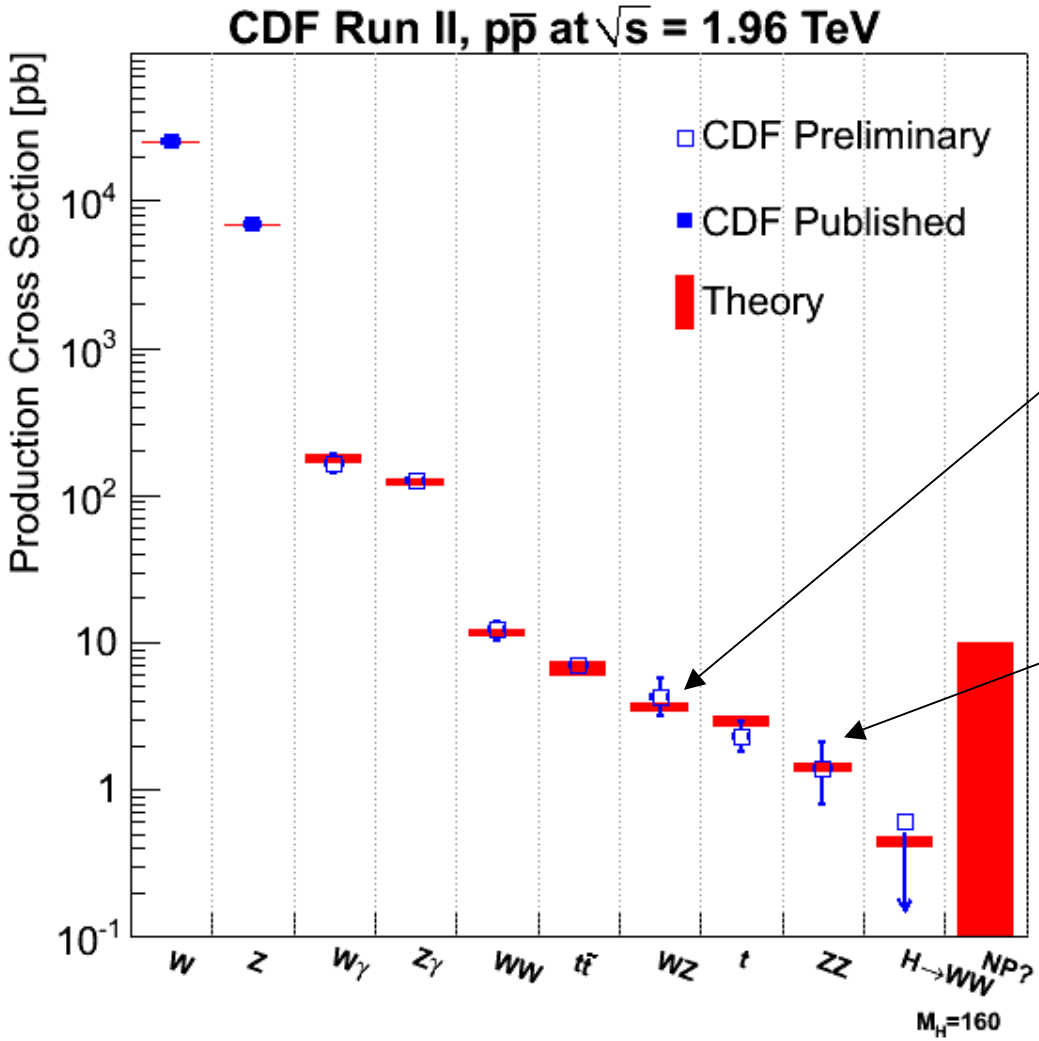


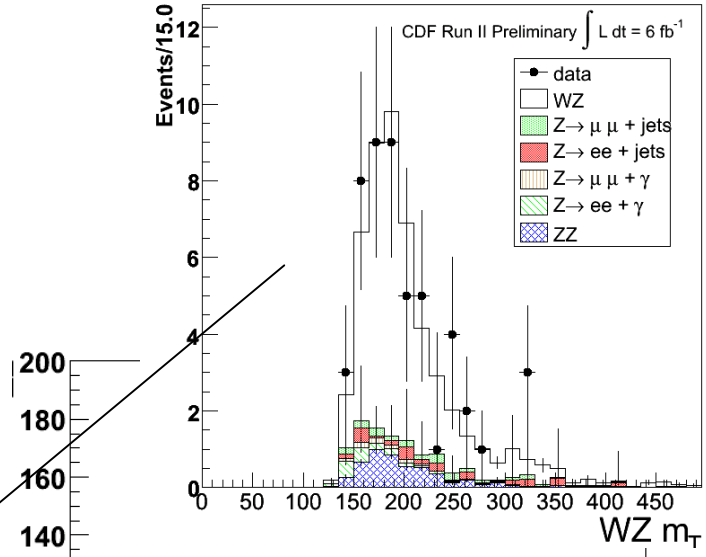
- Still far from SM

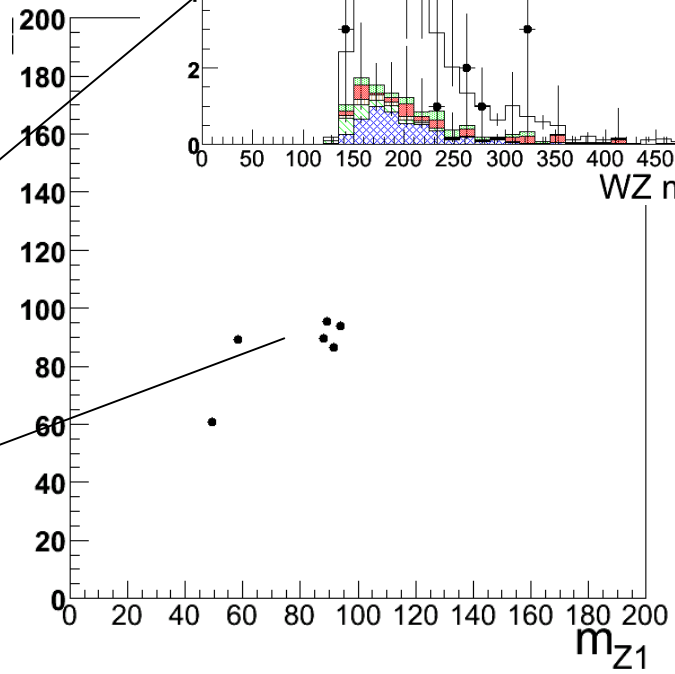
Results at mH = 120 GeV: 95%CL Limits/SM

Analysis	Lum (fb^{-1})	Exp. Limit	Obs. Limit
H→γγ	5.4	19.4	22.5

The last diboson: ZZ at >5σ





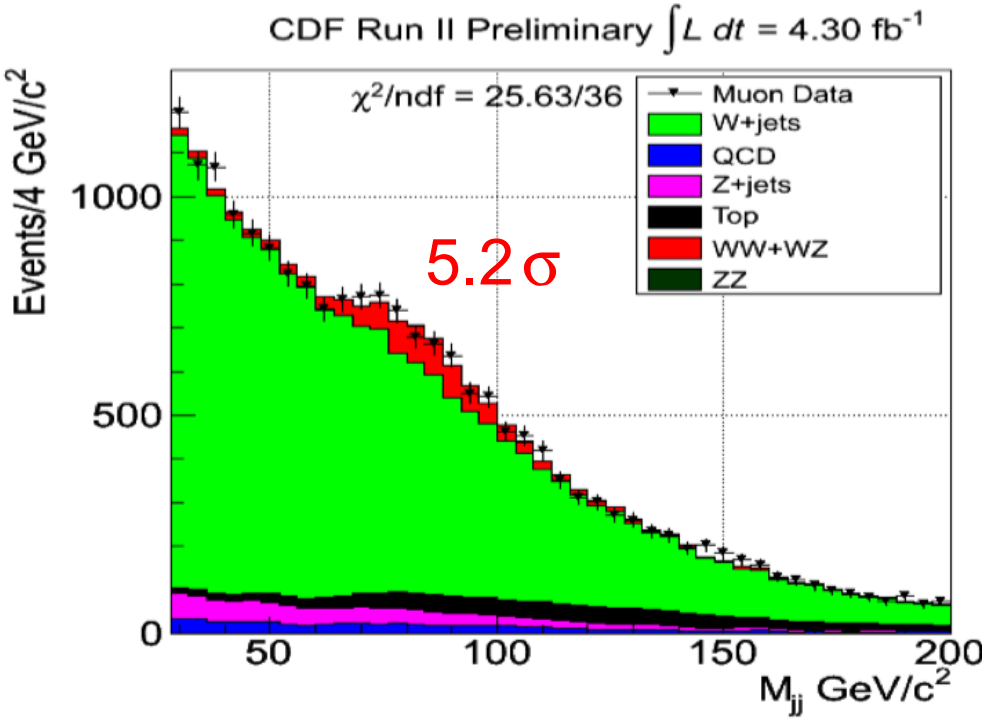


Complete set now

Perfect agreement with SM

Ability to observe diboson mass peaks in jet pairs

- WW/WZ lepton + Jets observation



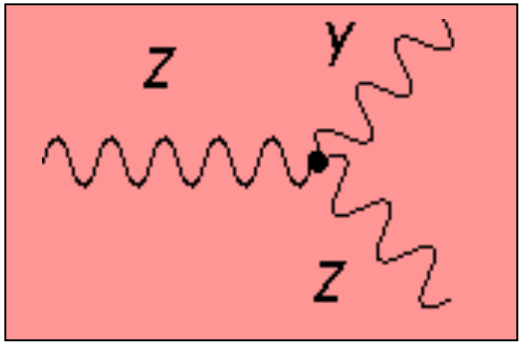
$\sigma = 18.1 \pm 3.3_{stat} \pm 2.5_{sys}$

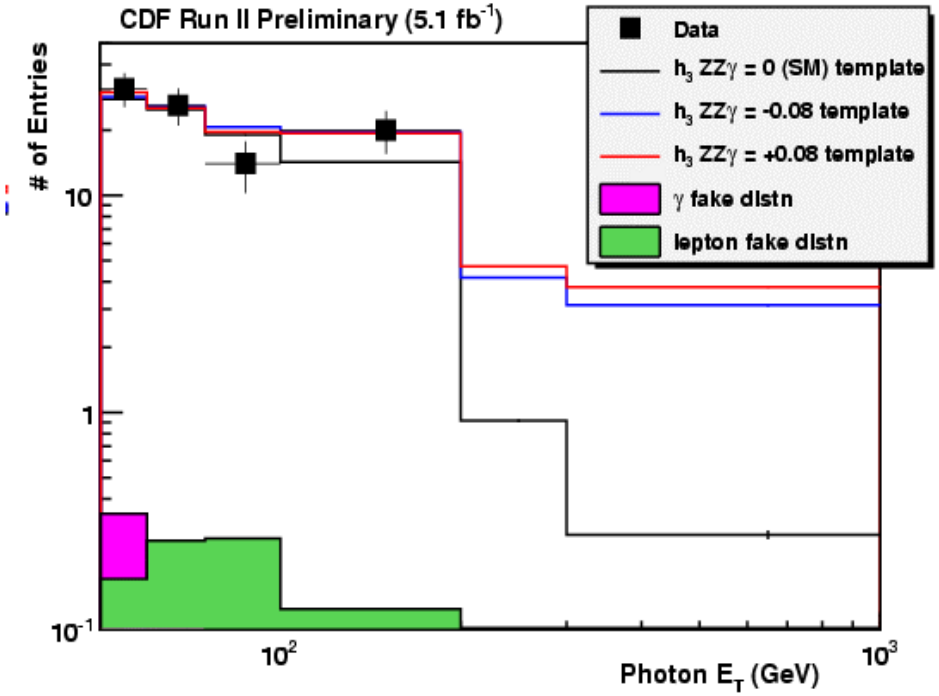
$\sigma = 16.5\ ^{+3.3}_{-3.0} \pm 3.5_{sys}$

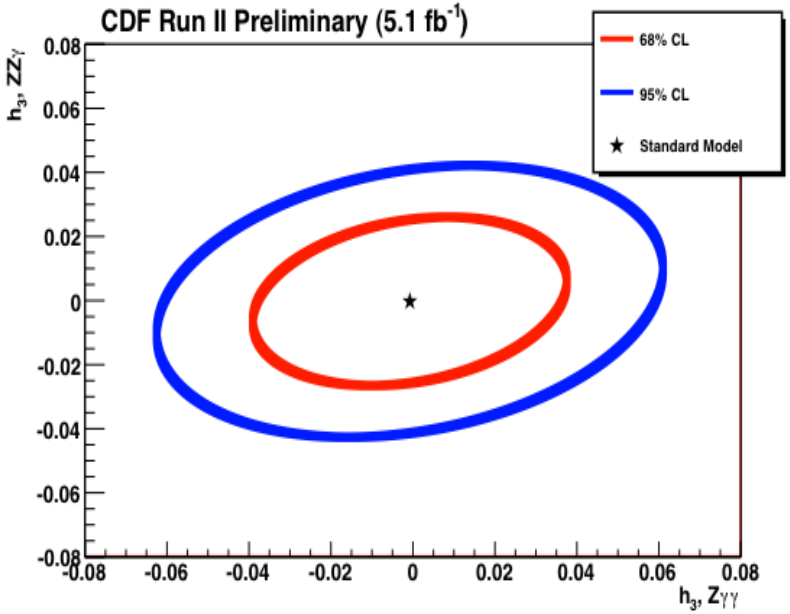
[SM = 15.1 ± 0.9 pb]

Anomalous Di-Bosons

- Zγ with 5.1 fb^{-1}
- Direct coupling would be anomalous
  - SM contribution from ISR and FSR





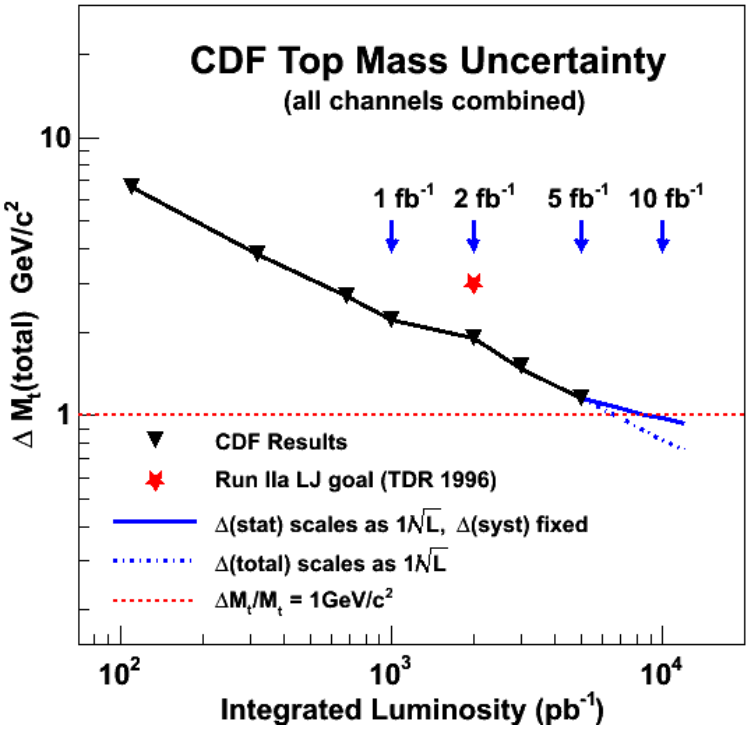


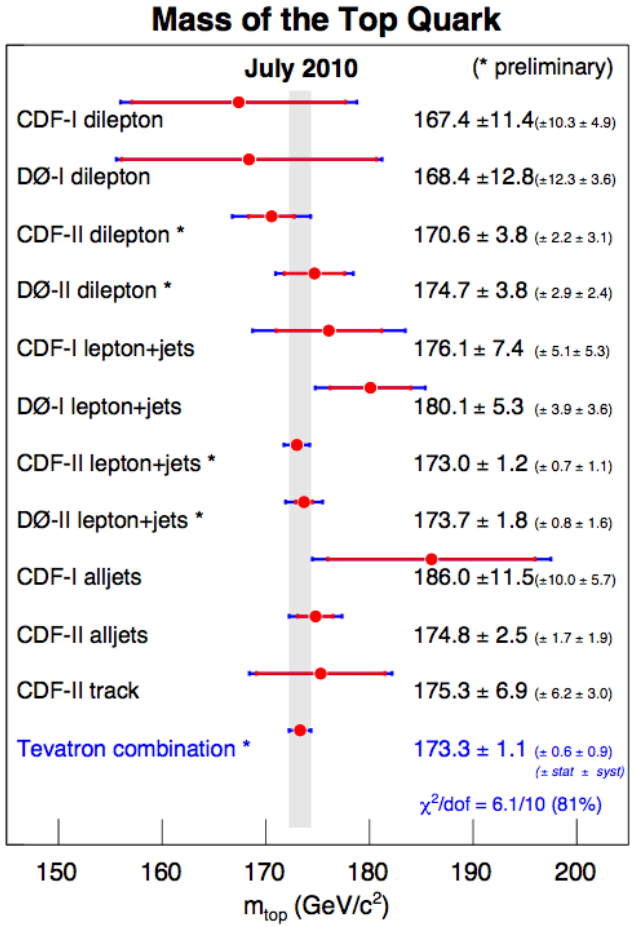
Limits (@ 1.2 TeV) : $|h_3| < 0.037$, $|h_4| < 0.0017$

Already significantly better than LEP & will improve (~ factor 2) with Z -> ννγ

Top Quark Mass (combined)

- July 2010 Tevatron Combination includes 11 results
- Largest systematic uncertainty is Jet Energy Scale (~ 0.46 GeV)
- Good agreement across both experiments and channels
- Single Experiment uncertainty of 1 GeV achievable in Run II:





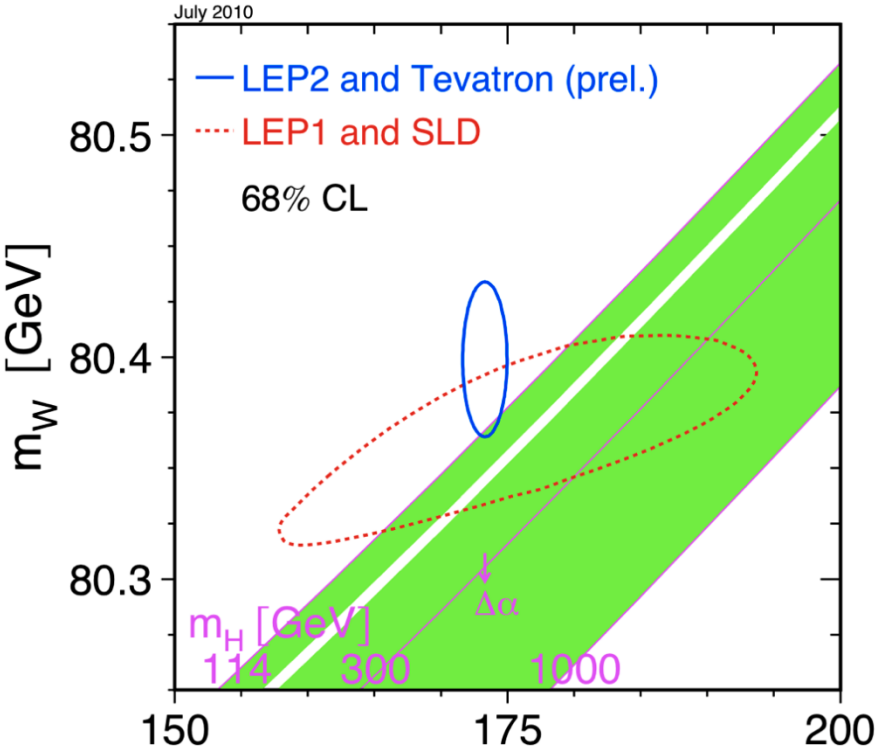
up to 5.6 fb^{-1} M_t = 173.3 ± 1.1 GeV

$\Delta M / M \sim 0.6\ \%$

Impact on indirect Higgs Mass

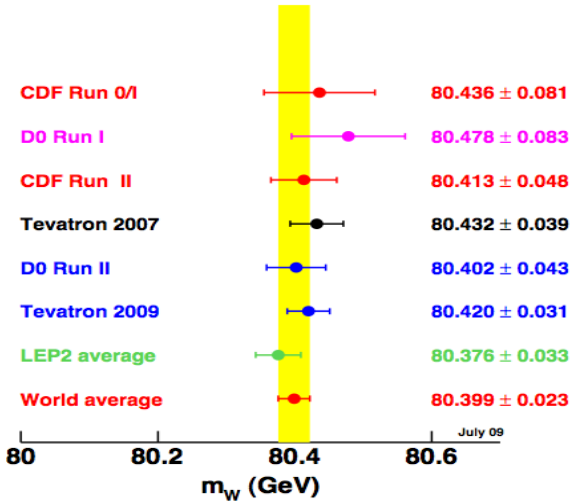
- Higgs Mass bounds from Electroweak Fit:

M_H < 158 GeV @ 95% CL
$M_H = 89^{+35}_{-26}$ GeV



- SM Higgs Mass constraint now driven by Δm_W
  - $\Delta m_W \sim 0.006 \times \delta m_{top} \sim 7$ MeV for equal weights in Higgs limits

Now 23 MeV - Expect significant update Summer '11



Single Top Cross section and $|V_{tb}|$

- Good precision

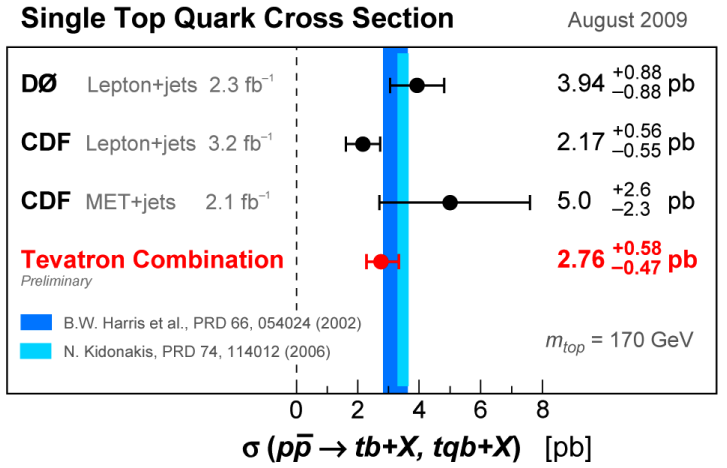
Tevatron combined result:

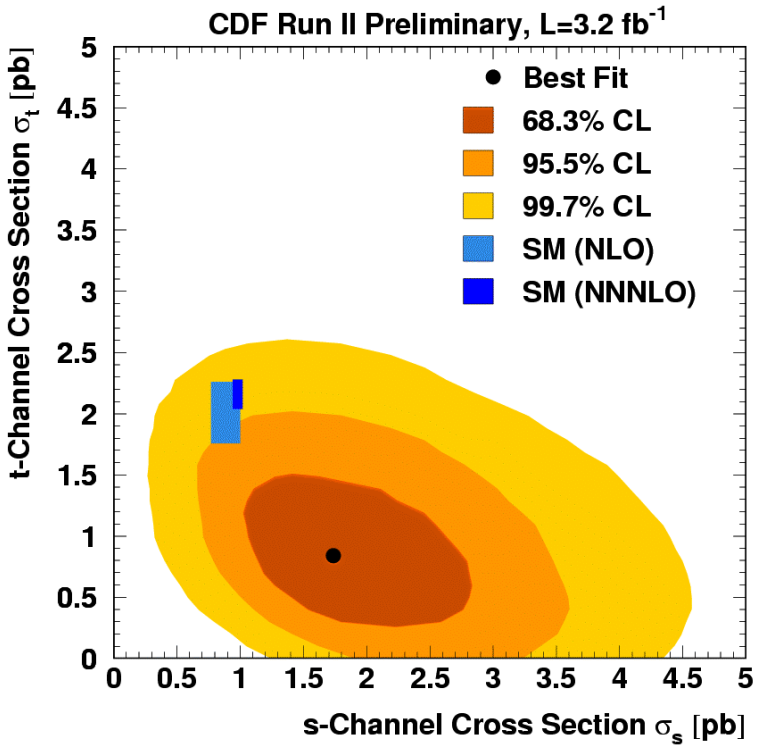
$\sigma_{s+t} = 2.76^{+0.58}_{-0.47}$ pb

$|V_{tb}| = 0.88 \pm 0.07$ (>0.77 @95% CL)

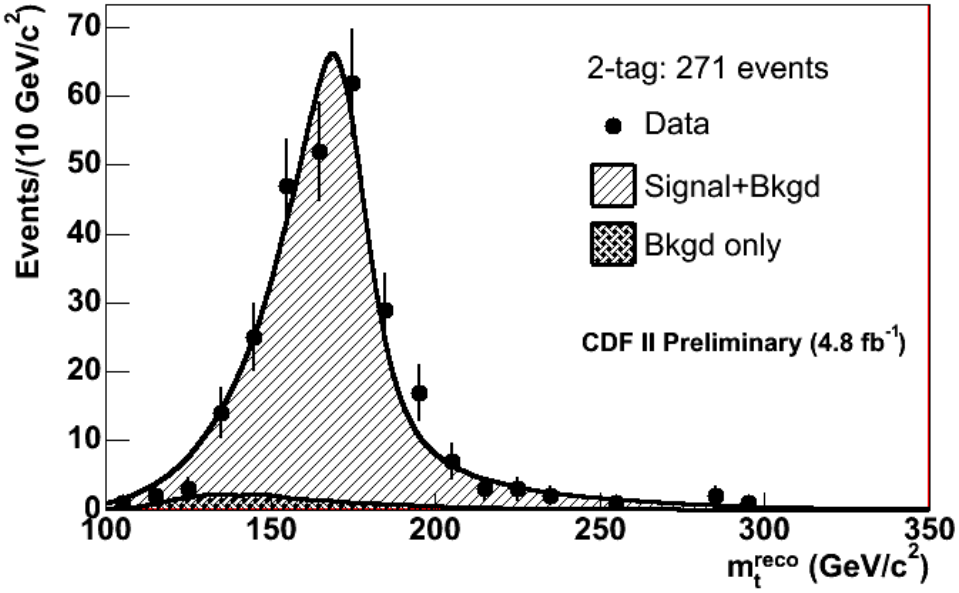
compatible with Standard Model
In all channels

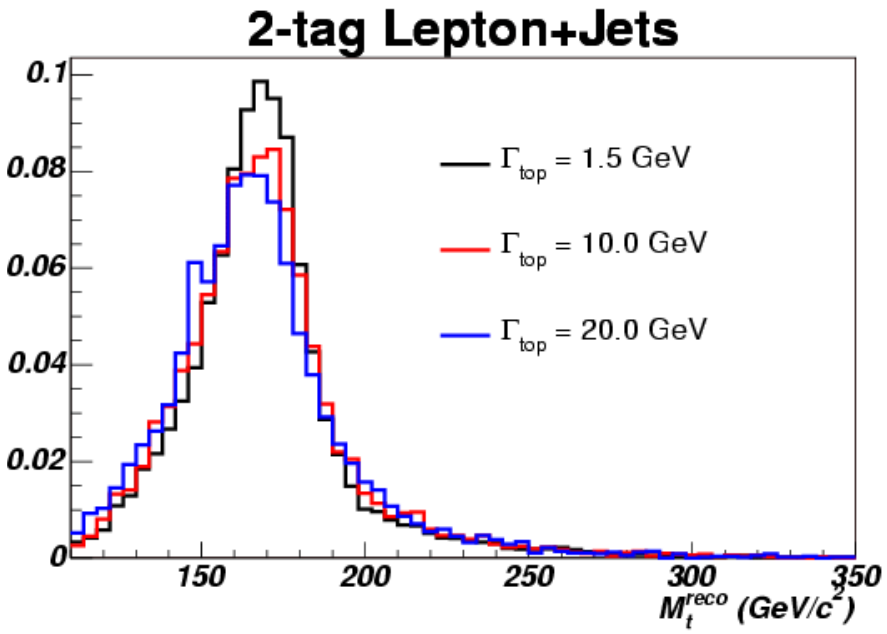
- Separate s- and t-channel:
  - Good overall agreement with Standard Model
  - ~2σ effect in CDF result
    Not explained by recent theory progress in t-channel signal MC (Campbell et al)





Direct measurement of top width





- CDF top samples so clean allow direct width measurement
  - Simultaneous constraint of jet energy scale using W jets

Γ_t<7.6 GeV (95%CL),
0.3<Γ_t<4.4 GeV (68%CL interval)

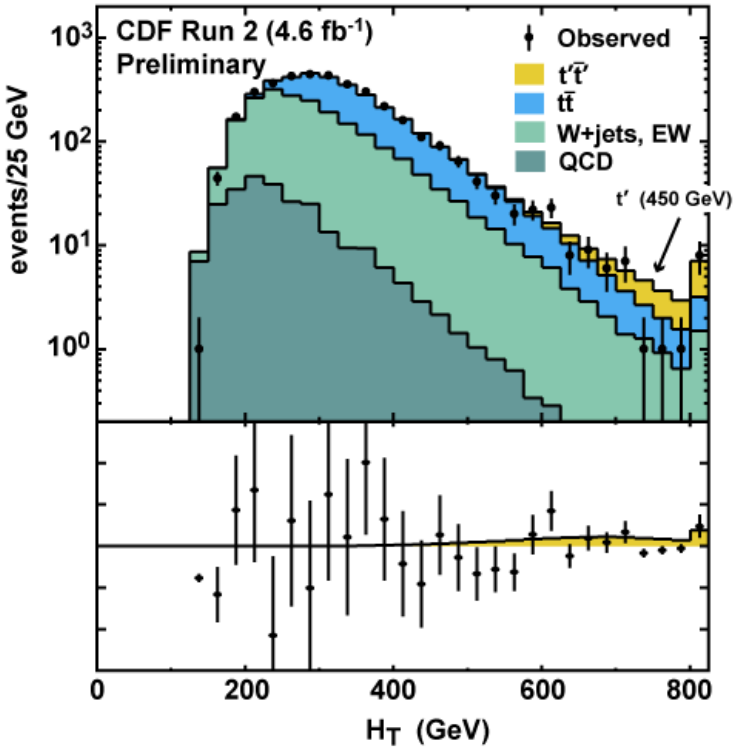
NLO: $\Gamma(t->Wb)$ = 1.26 GeV, m_t = 170 GeV

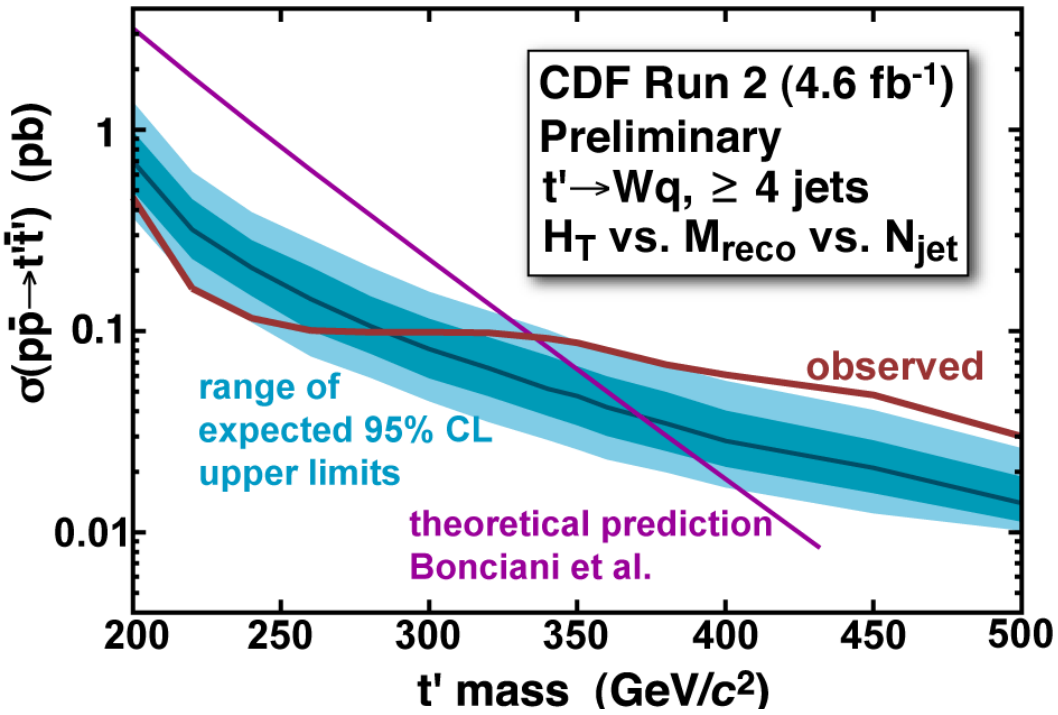
Big table of Top Properties Measurements

Property	Run II Measurement	SM prediction	Lumi (fb^{-1})
m_t	Tevatron: 173.3 ± 1.1 GeV		4.3-5.6
σ_{ttbar} (m_t=172.5 GeV) σ_{ttbar} (m_t=172.5 GeV)	CDF: 7.50 ± 0.31 (stat) ± 0.34 (syst) ± 0.15 (lumi) pb D0: 7.78 $^{+0.77}_{-0.64}$ pb	7.46 $^{+0.48}_{-0.67}$ pb / 6.41 $^{+0.51}_{-0.42}$ pb	4.5 1
$\sigma_{singletop}$ (@m_t=170 GeV)	Tevatron: 2.76 $^{+0.58}_{-0.47}$ (stat+syst)	2.86±0.8 pb	3.2-2.3
$\|V_{tb}\|$	Tevatron: 0.91 ± 0.08 (stat+syst)	1	3.2-2.3
σ(gg->ttbar)/σ(qq->ttbar)	D0: 0.07+0.15-0.07(stat+sys)	0.18	1
m_t - m_{tbar}	D0: 3.8 ± 3.7 GeV CDF -3.3±1.7 GeV	0	1
$\sigma_{ttbar+jets}$ (@m_t=172.5 GeV)	CDF: 1.6 ± 0.2 (stat) ± 0.5 (syst)	1.79+0.16 -0.31 pb	4.1
$c\tau_{top}$	CDF: 52.5μm @ 95%C.L.	10^{-10} μm	0.3
Top width	D0: Γ_t=2.05 +0.57 -0.52 GeV CDF: Γ_t < 7.6 GeV @ 95%C.L.	1.26 GeV	1
BR(t->Wb)/BR(t->Wq)	CDF: >0.61 @ 95% C.L. D0: 0.97 $^{+0.09}_{-0.08}$ (stat+syst)	1	0.2 0.9
W-boson Helicity	CDF: F_0=0.88 ±0.11 ±0.06 F_+=-0.15 ± 0.07±0.06 D0: F_0=0.67±0.08(stat)±0.07 (syst) F_+=0.02±0.04(stat)±0.03 (syst)	F_0 = 0.7 F_+ = 0	2 5.4
Charge	CDF: 4e/3 excluded with 87% C.L. D0: 4e/3 excluded at 92% C.L.	2/3	1.5 0.37
Spin correlations	CDF: κ = 0.7 ±0.6 ±0.3 (lj) D0: κ = -0.2 $^{+0.6}_{-0.5}$ (stat + syst) (ll)	0.78 $^{+0.027}_{-0.022}$	5.0 4.2
Charge asymmetry	CDF: 0.16 ± 0.07 % D0: 0.08 ± 0.04 %	0.05 +- 0.015 0.01 + 0.02 -0.01	5.3 4.3

4th generation: t' search

- Search for "heavy top" t' → Wq
  - Leptons + Jets events with 4.6 fb^{-1}
  - Reconstruct mass of t' and search in H_T and $m_{t'}$
  - **M(t') > 335 GeV** but tension just above the limit… update soon !



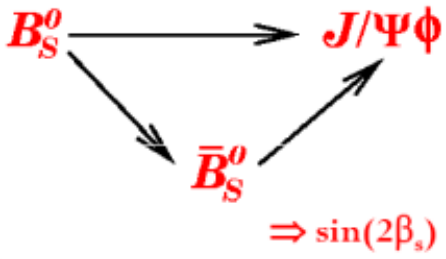


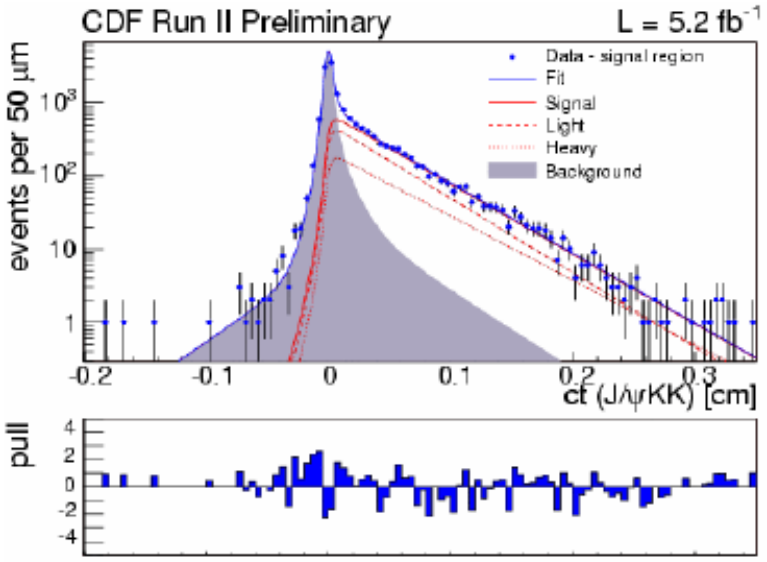
Sin(2βs)

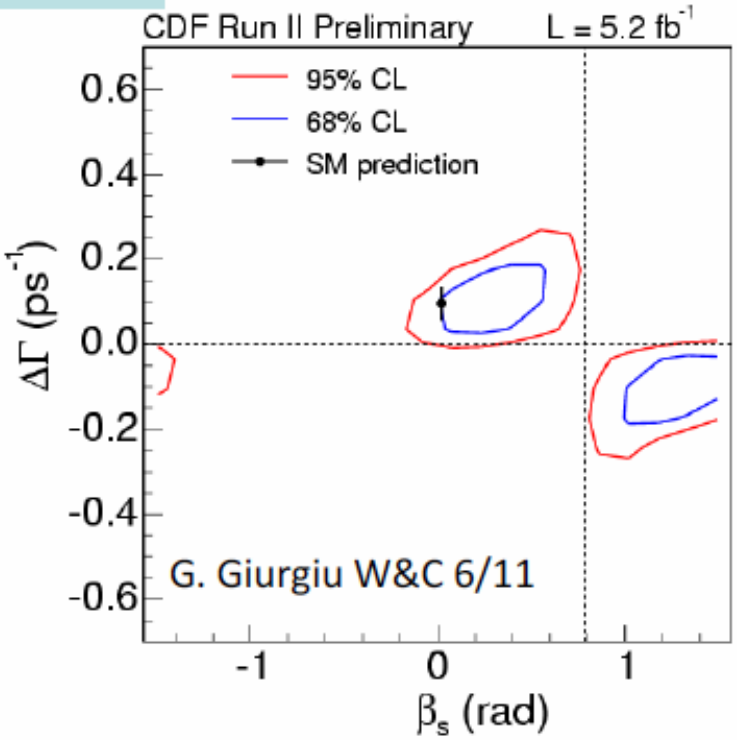
Interference of decays with/without mixing

Angular correlations of decay products to separate CP-even/CP-odd components as a function of proper time

Last summer, Tevatron combined result (2.8 fb^{-1}) consistent with SM at 3.4% level (2.1σ)







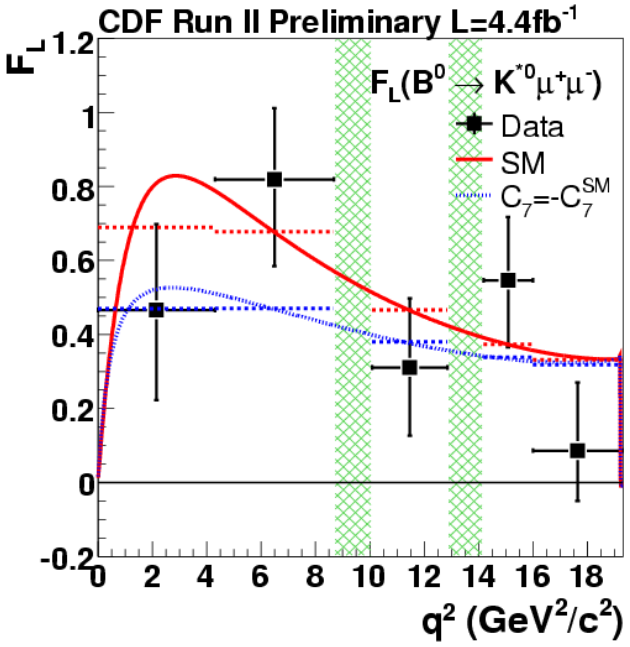
$c\tau_s = 458.7 \pm 7.5$ (stat) ± 3.6 (syst) μm
$\Delta\Gamma_s = 0.075 \pm 0.035$ (stat) ± 0.01 (syst) ps^{-1}
$|A_{||}(0)|^2 = 0.231 \pm 0.014$ (stat) ± 0.015 (syst)
$|A_0(0)|^2 = 0.524 \pm 0.013$ (stat) ± 0.015 (syst)

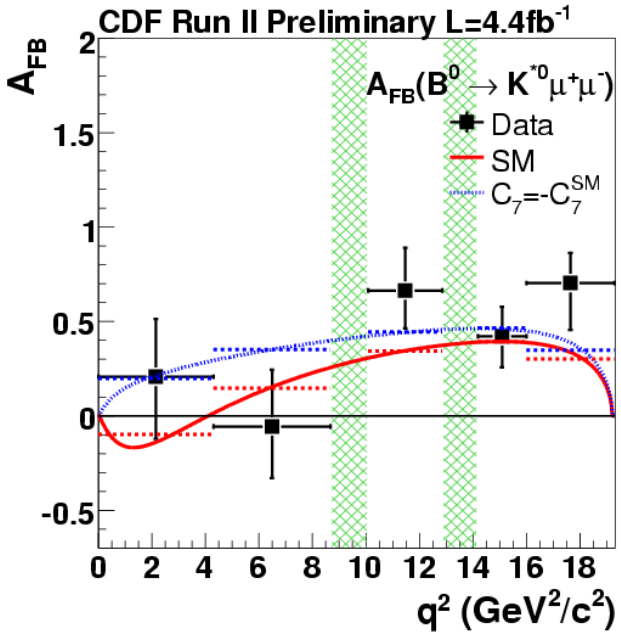
[0.02, 0.52] U [1.08, 1.55] at 68% CL
SM consistency 0.8σ (was 1.5σ)

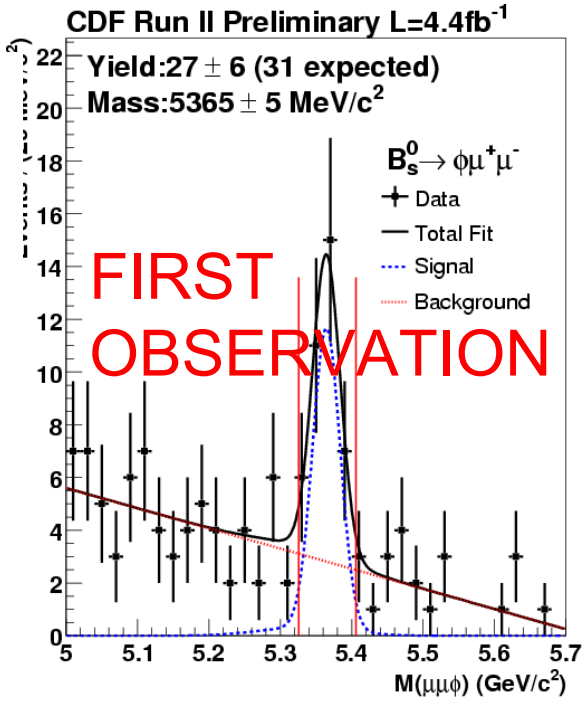
Improved precision - improved agreement with SM

Rare: B →μμX$_s$

- Rare decays B →μμX$_s$: B$^+$ →μμK$^+$, B^0 →μμK^{0*}, B$_s$ →μμφ
  - Measurement of A$_{FB}$(muons) and F$_L$(K^{0*})
  - FCNC process. Another way to probe for NP anomalies.
  - 4.4 fb-1 consistent (and comparable) with slight anomaly at B factories
  - First Observation of B$_s$ →μμφ!

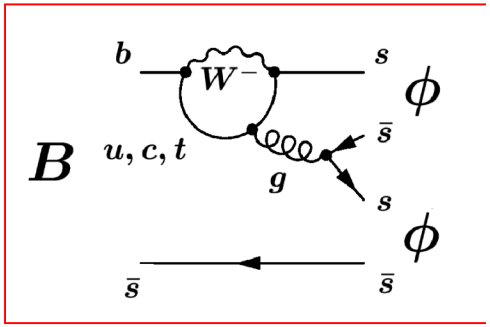




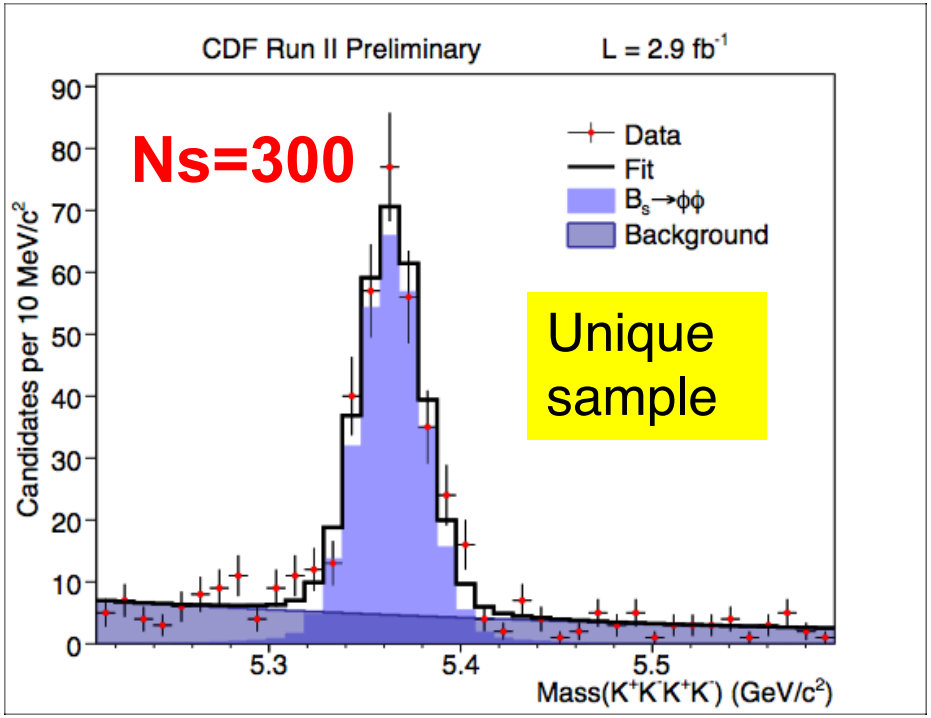


First measurement of $B_s \rightarrow \phi\phi$ polarization

- B factory charmonium vs. s penguin decays: ccs vs css. Discrepancy observed in sin2β and polarization
- Equivalent B_s test is: $B_s \rightarrow J/\psi\phi$(css) vs. $B_s \rightarrow \phi\phi$ (sss)
- First step is a polarization analysis.



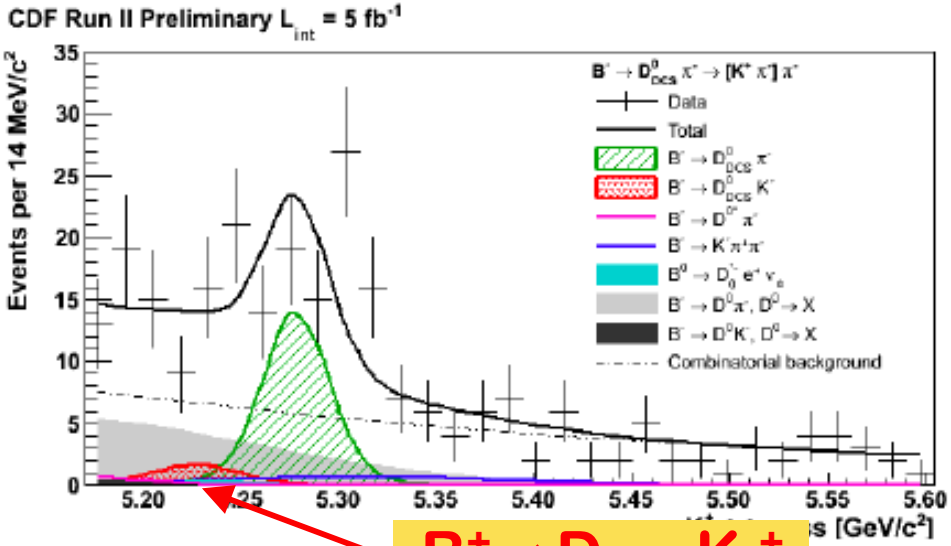
longitudinal (f_L)
$0.348 \pm 0.041(\text{stat}) \pm 0.021(\text{syst})$
transverse (f_T)
$0.652 \pm 0.041(\text{stat}) \pm 0.021(\text{syst})$



Expected higher f_L: **polarization puzzle is in the Bs too !**
Possibility of NP. Next: CPV.

First ADS analysis of B →DK (angle γ)

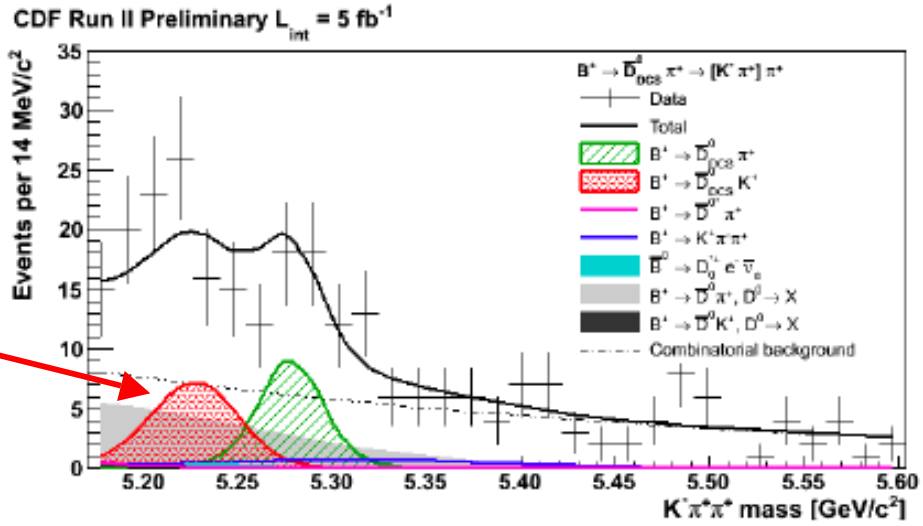
- Color suppress/doubly Cabibbo suppressed modes
- Combined significance (is there anything there?) >5σ



$B^+ \to D_{DCS} K^+$ evidence

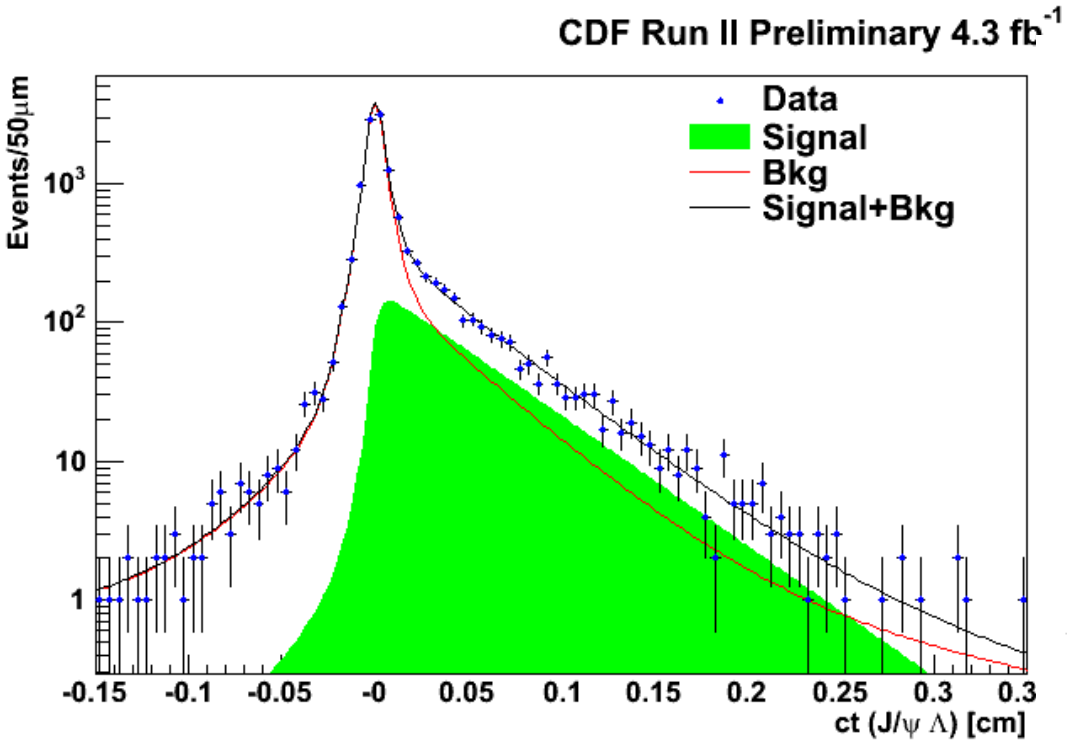
$$R_{ADS}(\pi) = 0.0041 \pm 0.0008(stat) \pm 0.0004(syst)$$
$$A_{ADS}(\pi) = 0.22 \pm 0.18(stat) \pm 0.06(syst)$$
$$R_{ADS}(K) = 0.0225 \pm 0.0084(stat) \pm 0.0079(syst)$$
$$A_{ADS}(K) = -0.63 \pm 0.40(stat) \pm 0.23(syst)$$

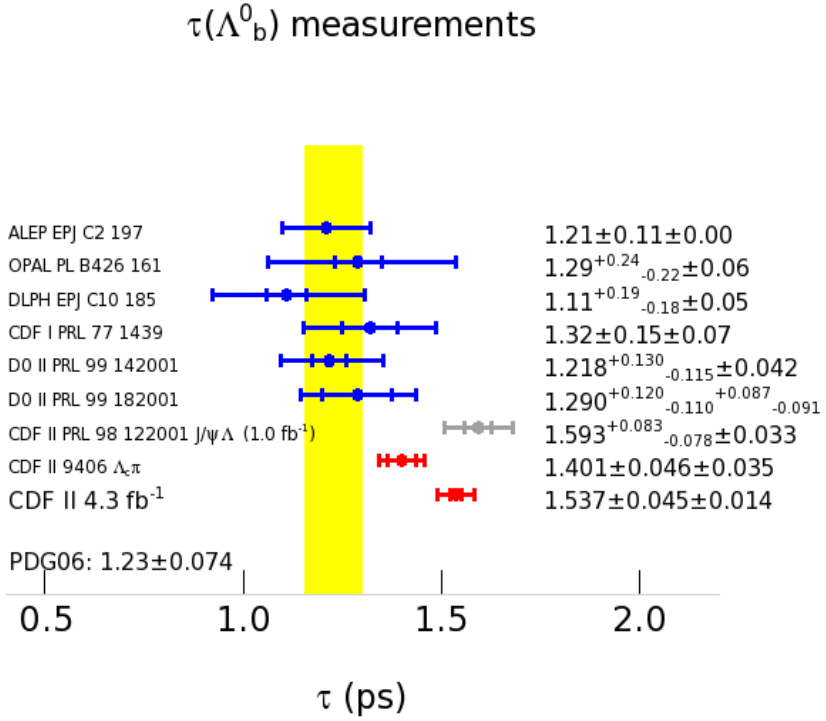
CDF 5 fb^{-1} result compares to Belle's full statistics



World's best B Hadron Lifetimes

- Now better than Y(4S) !
- B hadrons: $B^+ \rightarrow J/\psi K^+$, $B^0 \rightarrow J/\psi K^{0*}$, $\Lambda^0_b \rightarrow J/\psi \Lambda^0$



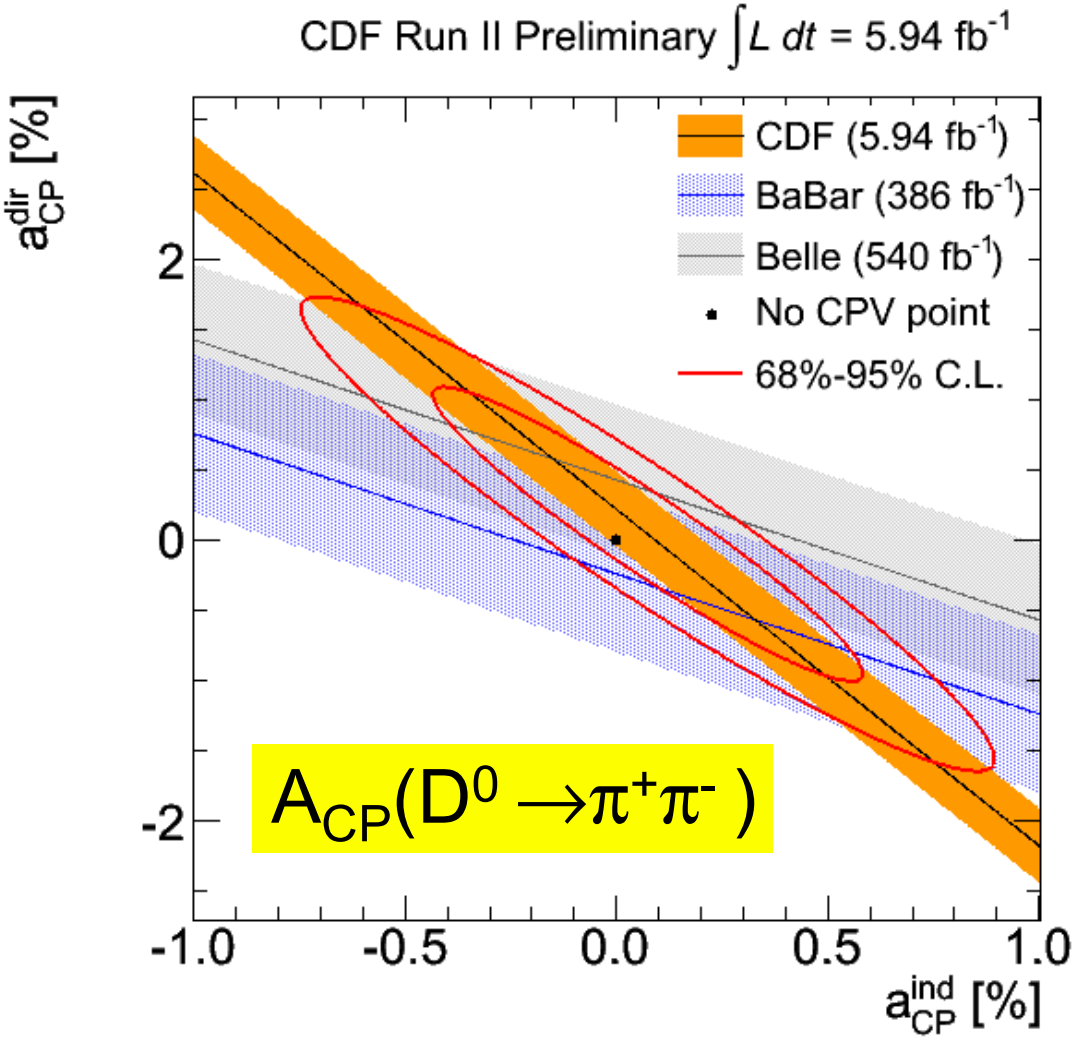


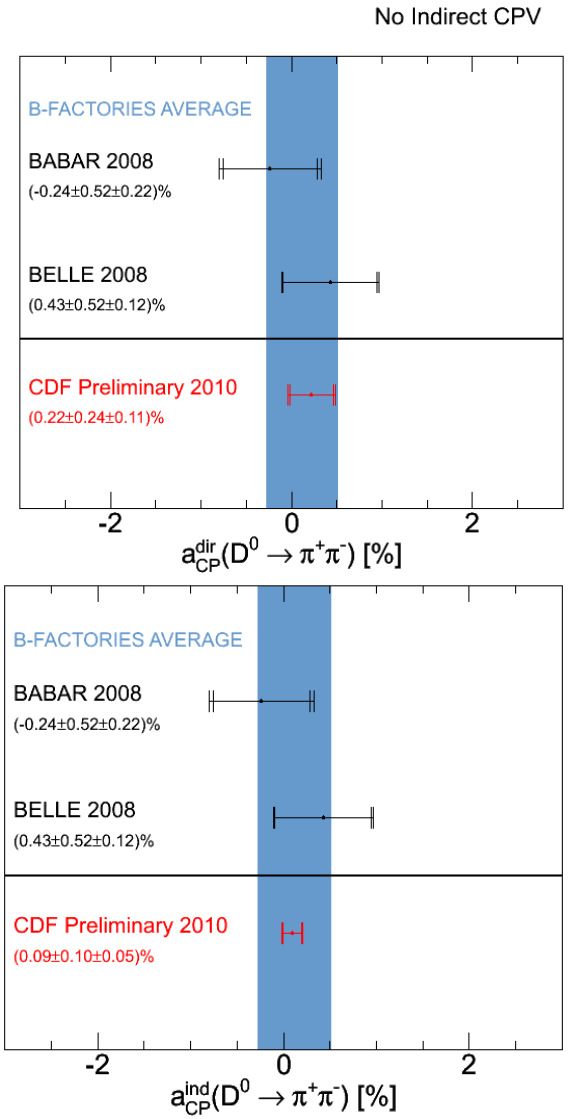
$\tau(B^+)/\tau(B^0) = 1.088 \pm 0.009_{stat} \pm 0.004_{sys}$

$\tau(\Lambda_b)/\tau(B^0) = 1.020 \pm 0.030s_{tat} \pm 0.008_{sys}$

Λ_b: $1.537 \pm 0.045_{stat} \pm 0.014_{sys}$ ps

Precision CP asymmetry in Charm





Unprecedented precision - significant probe for NP ! (and no effect seen)
Still statistics-limited ! And still need to add KK mode.

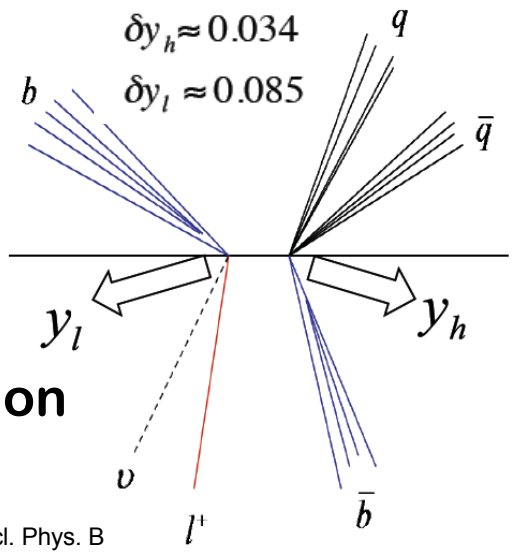
Very recent: A_{FB}(ttbar)

Top Quark A_{FB}

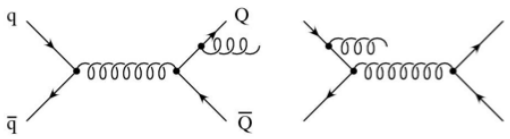
- **Test of discrete symmetries in strong interactions**

$$A_{FB} = \frac{N_{\Delta Y>0} - N_{\Delta Y<0}}{N_{\Delta Y>0} + N_{\Delta Y<0}}$$

- at Tevatron (pp), A_{FB} can be reconstructed in lab frame



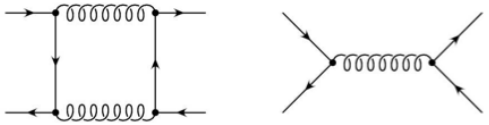
- **NLO QCD predicts small asymmetry A_{FB} ~ 5% in $q\bar{q} \rightarrow t\bar{t}$ – top quark preferentially in proton direction**



A_{FB} ~ - 7% (NLO)
A_{FB} ~ - 1% (NNLO)

S. Dittmaier, et al. Nucl. Phys. B Proc. Suppl. 183, 196 (2008).

$$\Delta y_{t\bar{t}} = q \cdot (y_l - y_h)$$
$$= y_t - y_{\bar{t}}$$
$$\Delta y_{t\bar{t}} = 2y_t^{t\bar{t}}$$
$$\delta\Delta y \approx 0.100$$



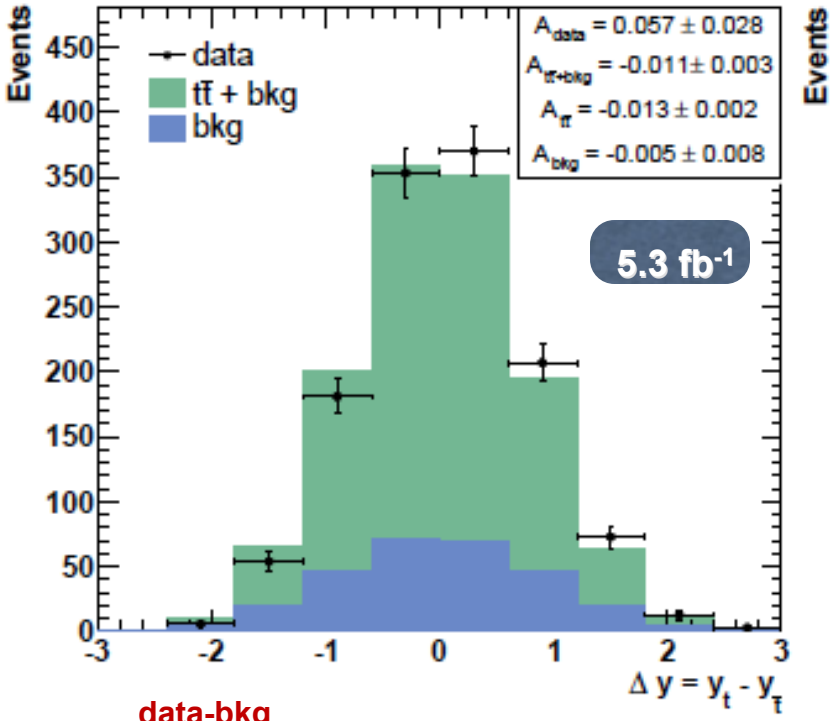
A_{FB} ~ +10-12% (NLO)
NNLO still missing

NEW !

- **New physics can modify/enhance A_{FB}**
  - **Extra heavy gluon octet, W', Z' with anom. couplings**
- **(Brand-) new CDF result based on 5.3 fb^{-1}** http://arxiv.org/abs/1101.0034
  - Δy (~ cos θ^*_{tt}) and M_{ttbar} (~ Q^2) dependence

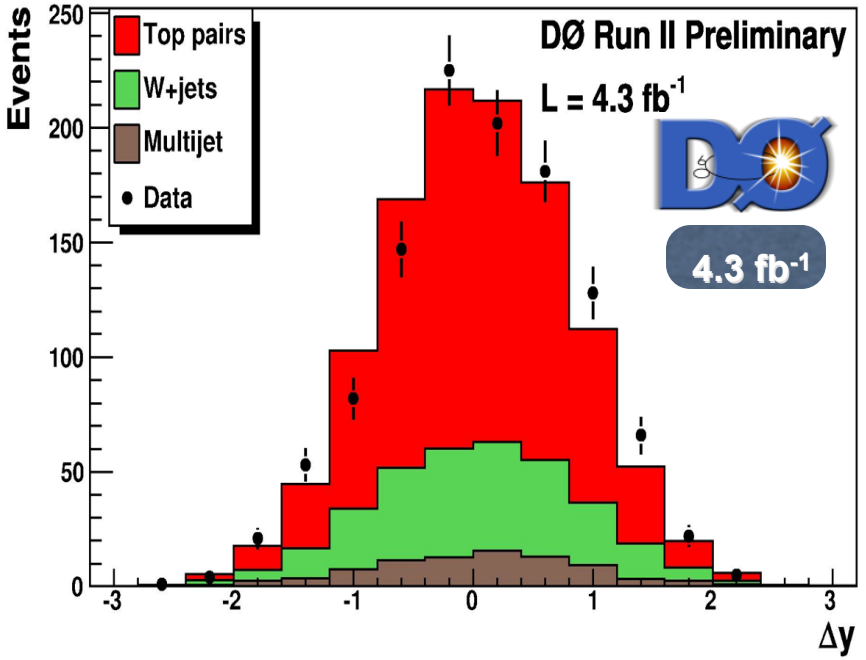
FNAL Wine and Cheese Seminar 7 January 2011!

Inclusive Asymmetries in $t\bar{t}$-Rest Frame



$A_{FB}^{data-bkg} = 7.5 \pm 3.7_{(stat+sys+thy)}$ %

$A_{FB}^{mc@nlo} = 2.4 \pm 0.5$ %



$A_{FB}^{data-bkg} = 8 \pm 4_{stat+sys}$ %

$A_{FB}^{mc@nlo} = 1^{+2.0}_{-1.0}$ %

Parton Level: (correcting acceptance, reconstruction, resolution, backgrounds)

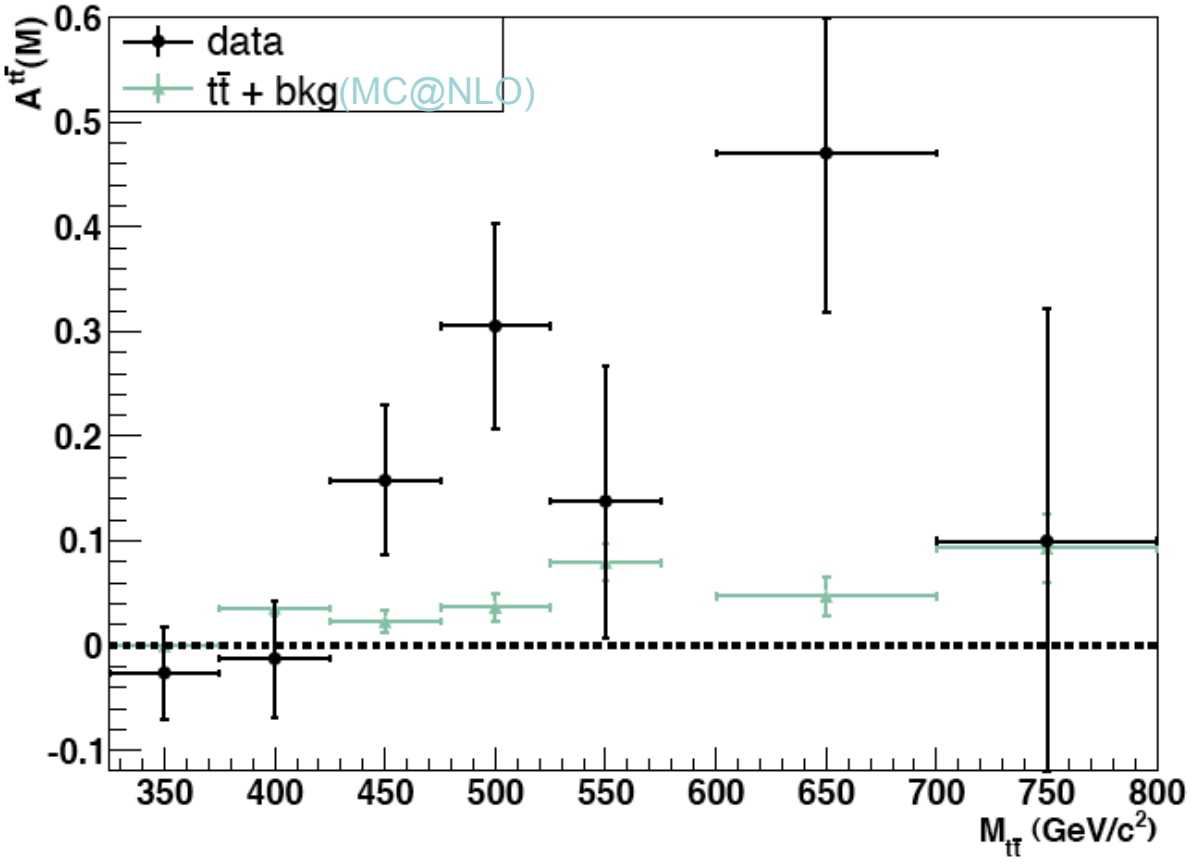
$A_{FB} = 15.8 \pm 7.4_{(stat+sys+thy)}$ %

$A_{FB}^{mcfm} = 5.8 \pm 0.9$ %

} ~ 1.5σ

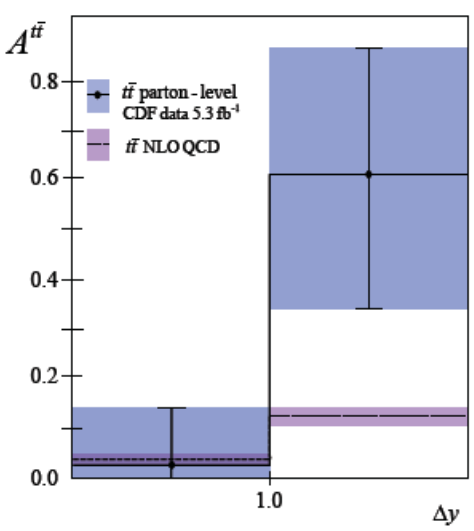
$M_{t\bar{t}}$ dependence

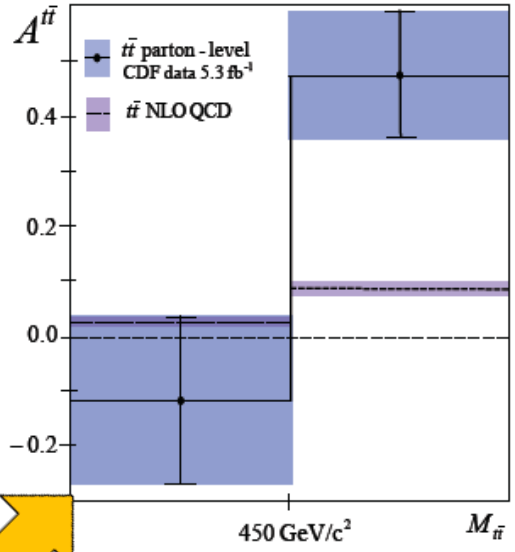
Reconstructed (data) level:

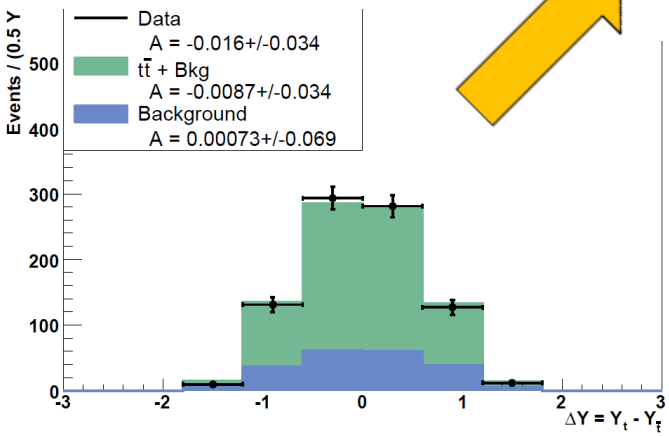


Reconstructed A_{FB} (data) overshoots MC@NLO prediction

Significant A_{FB} at high M_{tt} (and Δy)







~3.4σ

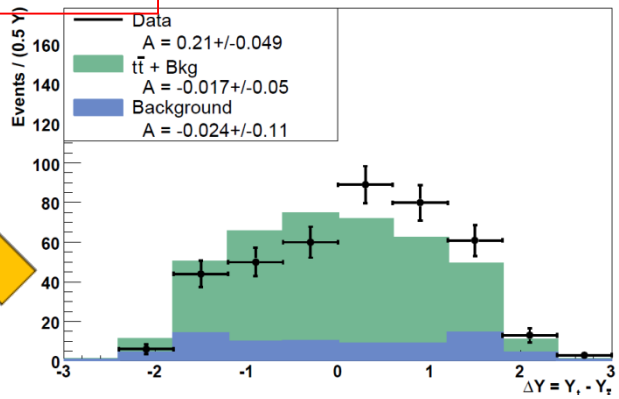


TABLE XIII: Asymmetry $A^{t\bar{t}}$ at high and low mass compared to prediction.

selection	$M_{t\bar{t}} < 450$ GeV/c^2	$M_{t\bar{t}} \geq 450$ GeV/c^2
data	-0.016 ± 0.034	0.210 ± 0.049
$t\bar{t}$+bkg (MC@NLO)	$+0.012 \pm 0.006$	0.030 ± 0.007
data signal	$-0.022 \pm 0.039 \pm 0.017$	$0.266 \pm 0.053 \pm 0.032$
$t\bar{t}$ (MC@NLO)	$+0.015 \pm 0.006$	0.043 ± 0.009
data parton	$-0.116 \pm 0.146 \pm 0.047$	$0.475 \pm 0.101 \pm 0.049$
MCFM	$+0.040 \pm 0.006$	0.088 ± 0.013

- cross checks: possible bias from unfolding physics model (Pythia versus Color Octet Model P. Ferrario,G. Rodrigo PRD80 051701 (2009)), reconstruction quality, lepton species, b-tagging/anti-tag cross check, jet multiplicity …

- Awaiting further theory input (NNLO) -

Interesting to see how this will evolve

Conclusion

Closing Thoughts

- CDF has had a very successful year
- We are making substantial efforts to capitalize on accumulated experience and sharpen all of our tools for best performance
- With these large datasets we are now stepping into a territory where anything can happen, and we are constantly on the watch for something unexpected.
- Treasures may await those that stay onboard the ship

BACKUP

25 Years of Luminosity